

Caracterização da poluição do ar: conceitos, fontes de poluição, tipos de poluentes e impactos.



Profa. Samara Carbone
26 de Abril de 2016

Por que estudar a poluição do ar?

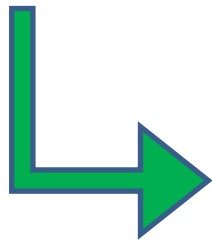


Cubatão em 1982

O problema é antigo...

↪ Múmias egípcias com SiO_2 e CE nos pulmões

Mas como, de onde ?



Indoor cooking



Substituição da lenha pelo carvão no século XIII

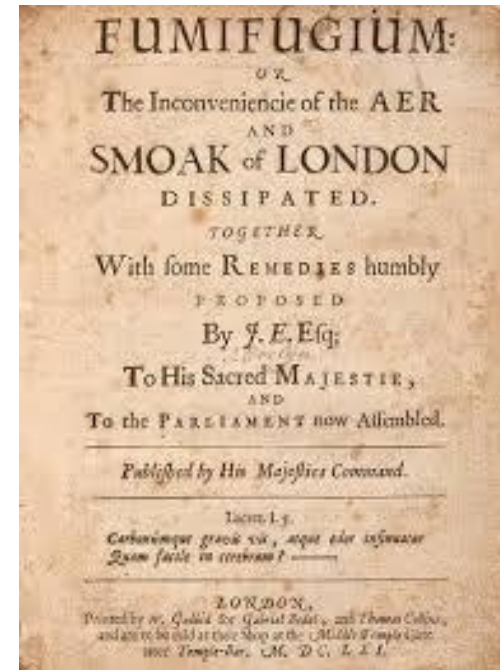
Escassez de lenha perto das cidades na Inglaterra

Uso de carvão

Link entre poluição e a saúde

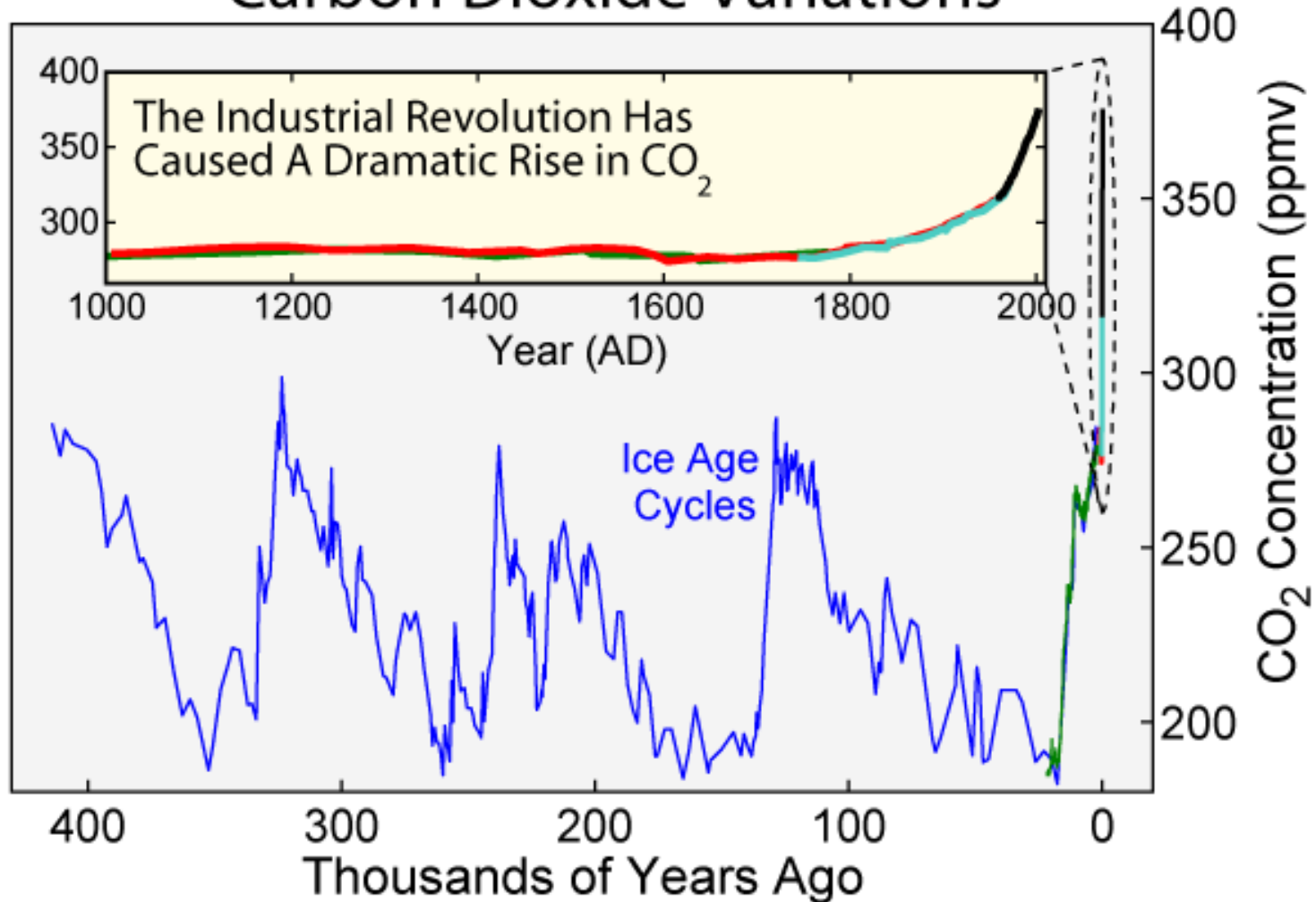
Pequena era do gelo no século XVII e o aumento do uso de carvão

Tentativa de regularização (1661)



A revolução industrial intensificou o problema

Carbon Dioxide Variations



O problema persiste, mesmo em países desenvolvidos

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14 March 2014 Last updated at 11:35 GMT

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Paris offers free public transport to reduce severe smog



The Eiffel Tower and other landmark buildings in Paris have disappeared in a milky fog

Authorities in Paris have taken the rare step of making public transport free for three days to reduce severe smog caused by unusually warm weather.

The French capital region and 30 other departments have been on maximum pollution alert for several days.

Landmark buildings like the Eiffel Tower were barely visible after a white fog settled over Paris.

Related Stories

▶ [Free Paris travel as pollution rises](#)

[Air pollution 'still harming health'](#)

[Milan bans cars to stop pollution](#)


Objetivos da aula de hoje

- ✓ Quais são os poluentes atmosféricos?
- ✓ De onde eles vem? Quais são as suas fontes?
- ✓ Quais os impactos dos poluentes nas diferentes escalas (local, regional e global)?

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O que é poluente atmosférico?




Gases e partículas sólidas/líquidas resultantes de atividades humanas e de fenômenos naturais dispersos no ar atmosférico.



Com efeitos adversos a saúde e/ou ao meio ambiente

(EPA, 2016)

Exemplos de poluentes atmosféricos

 CO, SO_x, NO_x, O₃, COV, CH₄, fuligem, CE, MP entre outros.

COV - Compostos orgânicos voláteis

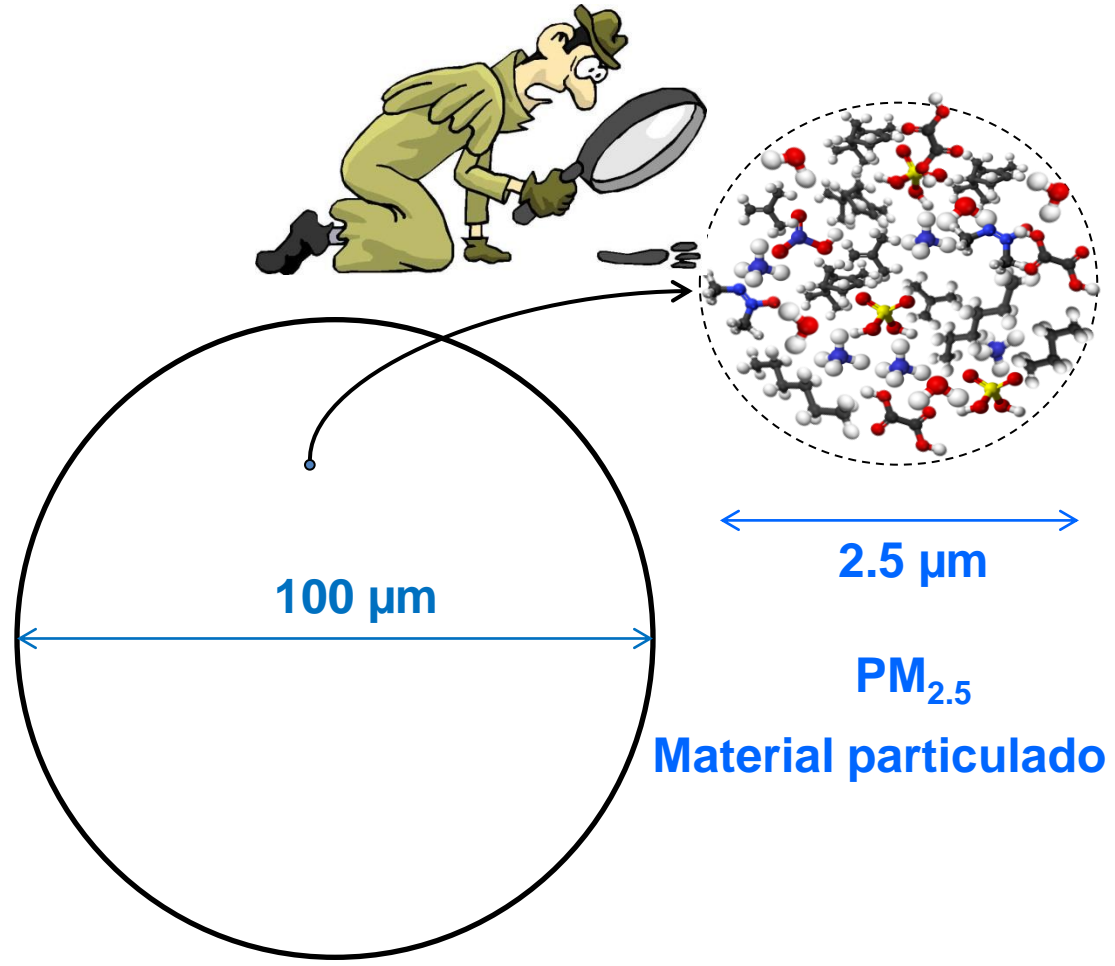
Pressão de vapor > 0.27 KPa

MP - Material particulado: mistura complexa de partículas sólidas e ou líquidas em suspensão na atmosfera, menores que 100 μm.

MP₁₀ = MP com diâmetro < 10 μm

MP_{2.5} = MP com diâmetro < 2.5 μm

Material particulado ou aerossóis

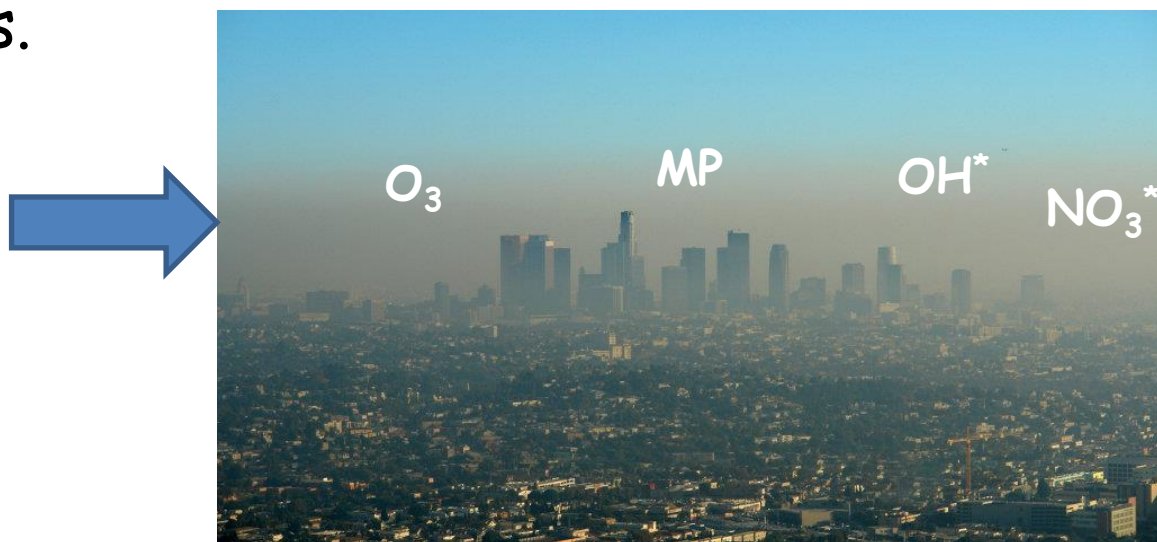


São classificados em primários e secundários

Poluentes primários: emitidos diretamente para a atmosfera.



Poluentes secundários: se formam na atmosfera a partir dos precursores.



Fog e smog associados à morbidade e mortalidade

Londres 1952

Los Angeles 1958

WORSE THAN 1866 CHOLERA

Deaths After Fog

The rise in deaths in the week after London's great fog early in December was greater than that in the worst week of the cholera epidemic in 1866. This is disclosed in a report of the health

5 MIGS DOWNED, NATIONALISTS SAY

Times Telephone Numbers
 • MAdison 8-2348 for advertising services
 • MAdison 8-2349 for advertising services
 • MAdison 8-4411 for all classified advertising work.

Los Angeles Times 9 A.M. FINAL

LIBERTY UNDER THE LAW THE INDUSTRIAL FREEDOM

VOL. LXXVIII IN FOUR PARTS FRIDAY MORNING, SEPTEMBER 19, 1958 76 PAGES DAILY 16c

ANOTHER SMOG ALERT EXPECTED HERE TODAY

Dulles Urges Prompt Formosa Strait Truce

Would Set Stage for Settlement

FIRST GI HIT IN SHELLING ON QUEMOY



SMOG SUPREMACY—Harry Nelson, passing Union Station, wipes his streaming eyes as he walks through smog that nearly hides the Civic Center in the background. Yesterday's smog attack brought the year's first alert, which lasted for 2 hours and 24 minutes.

Forecast Calls for 94 High

Los Angeles, gasping after yesterday's worst smog attack of the season, faces a possible second alert today, the Air Pollution Control District has warned.

The Weather Bureau said the temperature in the atmosphere here is expected to hit a smoldering 94 degrees by noon today.

The APCD, in predicting the city is due for another smog alert, pleaded with motorists to curtail their driving to keep the hazard from intensifying.

Waves in 41 Months

The concentration of aerosols in the atmosphere here yesterday was the worst Los Angeles has seen for 14 months.

The Weather Bureau said the temperature in the atmosphere here is expected to hit a smoldering 94 degrees by noon today.

The APCD, in predicting the city is due for another smog alert, pleaded with motorists to curtail their driving to keep the hazard from intensifying.

TEMPERATURES

1:00 p.m.	68	1:00 p.m.	65
2:00	67	2:00	64
3:00	67	3:00	65
4:00	67	4:00	65
5:00	67	5:00	65
6:00	67	6:00	65
7:00	67	7:00	65
8:00	67	8:00	65
9:00	67	9:00	65
10:00	67	10:00	65
11:00	67	11:00	65
12:00	67	12:00	65

UNITE STATES

China's Secretaries

UNITED STATES SECRETARIES—The Communist Party of the United States today called for a prompt ceasefire in the Formosa Strait that would set the stage for peaceful negotiations of all issues in that powder keg zone.

In a daily news release, Secretary of State Dulles today called for a prompt ceasefire in the Formosa Strait that would set the stage for peaceful negotiations of all issues in that powder keg zone.

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Red Charges

Nationalists Claim Five MIGs Downed

Red Charges—The American Embassy in Peking today charged that the Chinese Communist Party had shot down five MIGs in the Formosa Strait.

Nationalists Claim Five MIGs Downed—The Nationalist government in Taipei today claimed that it had shot down five MIGs in the Formosa Strait.

Red Charges

Girl Crushed to Death in Elevator at Home

Red Charges—The American Embassy in Peking today charged that the Chinese Communist Party had shot down five MIGs in the Formosa Strait.

Girl Crushed to Death in Elevator at Home—A young girl was crushed to death in an elevator at her home in Los Angeles today.

Red Charges

Daughter of Financier Dies in La Jolla Slumber Party Tragedy as Parents Absent

Red Charges—The American Embassy in Peking today charged that the Chinese Communist Party had shot down five MIGs in the Formosa Strait.

Daughter of Financier Dies in La Jolla Slumber Party Tragedy as Parents Absent—A young girl died in a slumber party in La Jolla today.

Red Charges

Gasoline Prices Sag in Southland

Red Charges—The American Embassy in Peking today charged that the Chinese Communist Party had shot down five MIGs in the Formosa Strait.

Gasoline Prices Sag in Southland—Gasoline prices sagged in the Southland today.

Red Charges

SAMPLE PUZZLE GIVEN FOR ROAD TO RICHES

Red Charges—The American Embassy in Peking today charged that the Chinese Communist Party had shot down five MIGs in the Formosa Strait.

SAMPLE PUZZLE GIVEN FOR ROAD TO RICHES—A sample puzzle was given for a road to riches today.

THE WEATHER

Forecast for Los Angeles: Partly cloudy, with a high of 94 and a low of 65.

Los Angeles, Calif. (AP)—The weather here today is expected to be partly cloudy with a high of 94 and a low of 65.

No entanto, fog e smog são bem diferentes

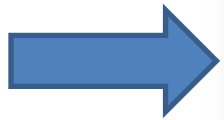
Londres 1952
Fog

- SO₂ e fuligem
- H₂SO₄ e aerossóis
- Alta UR
- Pico de poluição de manhã
- Baixas temperaturas, < 2°C

Los Angeles 1958
Smog

- COVs, NO_x
- O₃, PAN, HNO₃
- Baixa UR
- Pico de poluição à tarde/noite
- Altas temperaturas, >23°C

SMOG fotoquímico em São Paulo



Smog = Smoke + fog

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De acordo com a fonte emissora são classificados em naturais e antropogênicos/antrópicos

Naturais: emitidos naturalmente.



De acordo com a fonte emissora são classificados em naturais e antropogênicos/antrópicos

↪ Antrópicos: emitidos devido às atividades humanas.



As fontes antrópicas podem e DEVEM ser controladas

São resultantes principalmente da combustão incompleta de combustíveis fósseis

 Combustão completa

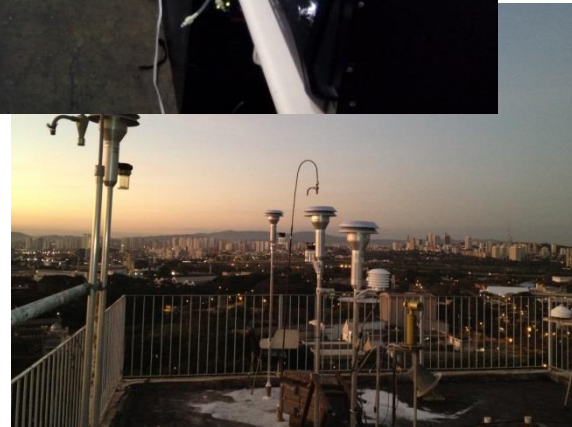


 Combustão incompleta



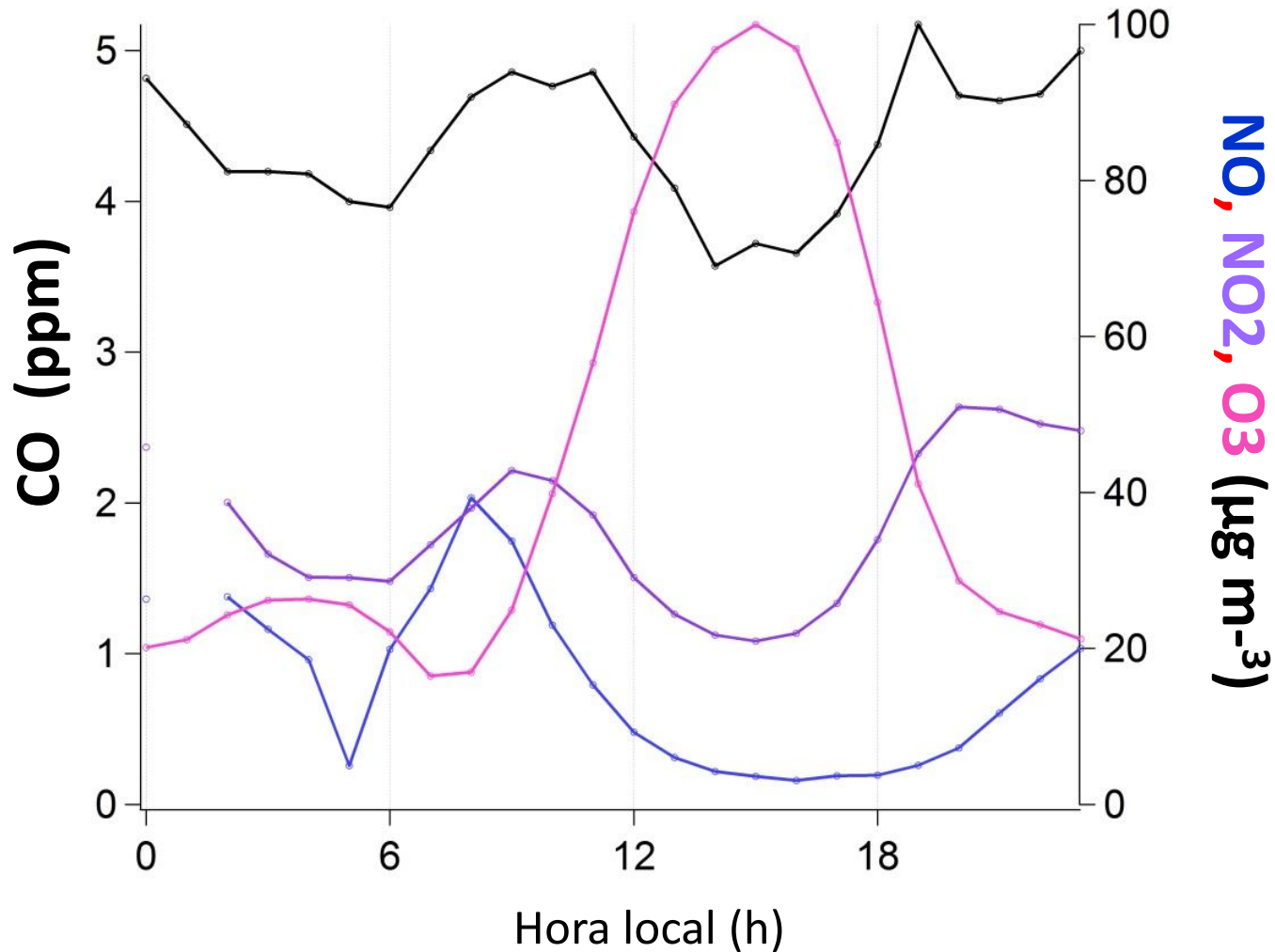
Presença de átomos de S e N.

Mas onde são medidos e como?



Perfil diário de medidas de gases em São Paulo?

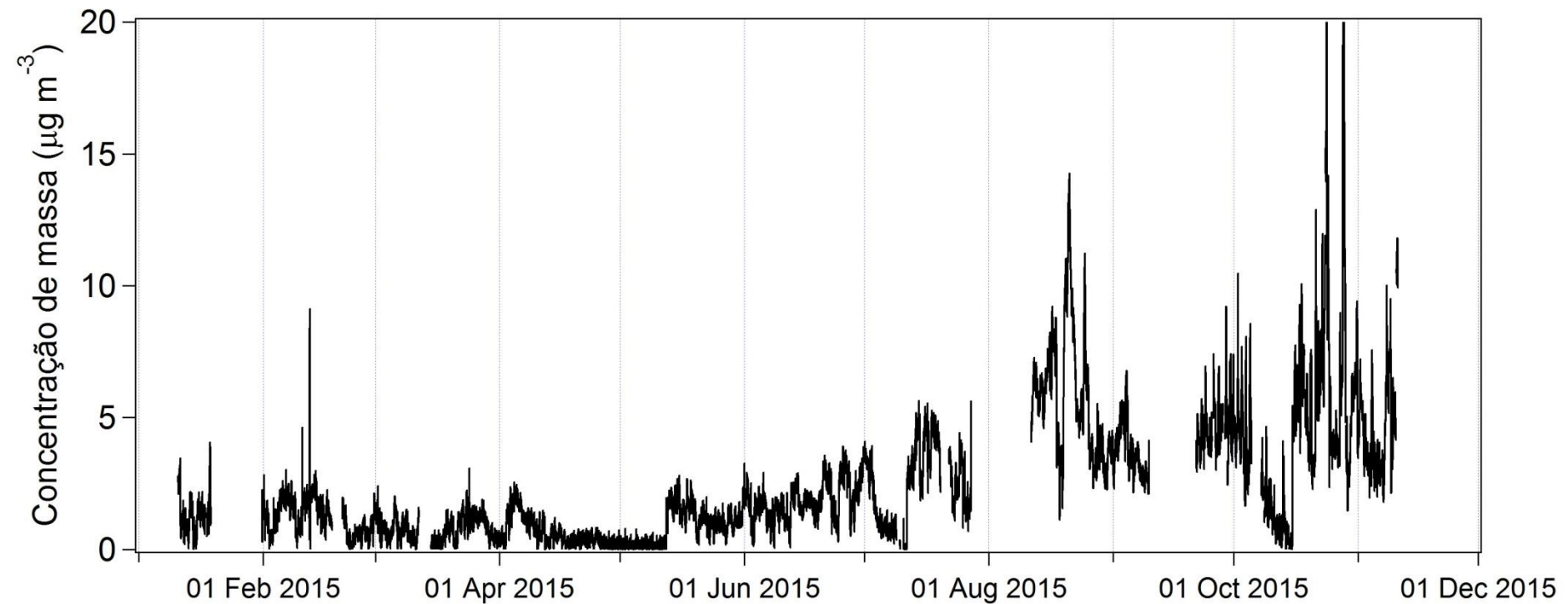
Média de Junho a Outubro de 2015



Medidas contínuas são feitas na floresta Amazônica



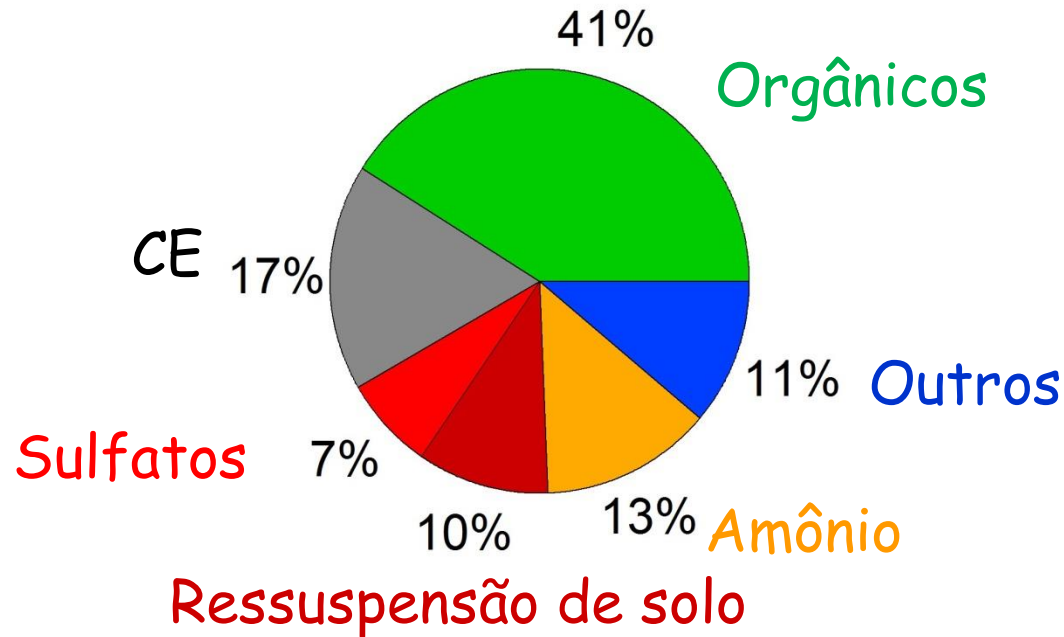
Série temporal de concentração de MP_{2.5} na floresta Amazônica



(Carbone et al., em preparação)

Quem veio de onde ? E quanto?

Composição média do $MP_{2.5}$ em São Paulo



(Brito et al., 2013)

Traçadores atmosféricos representam a impressão digital de uma fonte poluidora



Veículos leves

vs

veículos pesados

- ✓ CO
- ✓ COV

- ✓ NO_x
- ✓ MP
- ✓ SO₂
- ✓ COV



Navios: SO₂, V e Ni

Emissão industrial e seu traçadores



Emissões industriais

✓ Termelétricas: Emissão de CO , SO_2 , $COVs$, fuligem, ...

✓ Cerâmica: SO_2 , CO , Al , Ti , Fe

✓ Cimenteiras: Ca , Na , Si

✓ Metalúrgicas:

Produção de aço - Fe , alumino-silicatos ($Al_2O_3 \cdot SiO_2$), Cl

Produção de Cu , Al



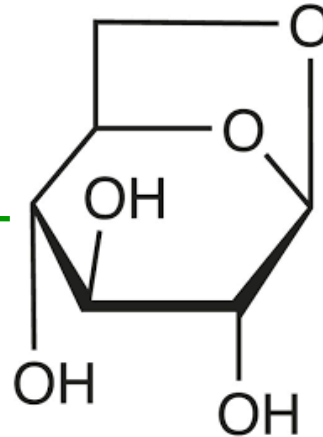
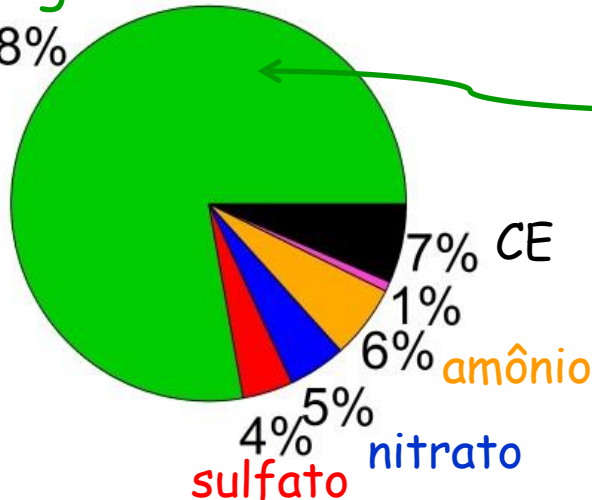
Emissão por agricultura principalmente na forma de queima de biomassa

COV, CO, CO₂, MP

MP_{2.5}: destacam-se o K e nos aerossóis orgânicos a molécula de levoglucosan.

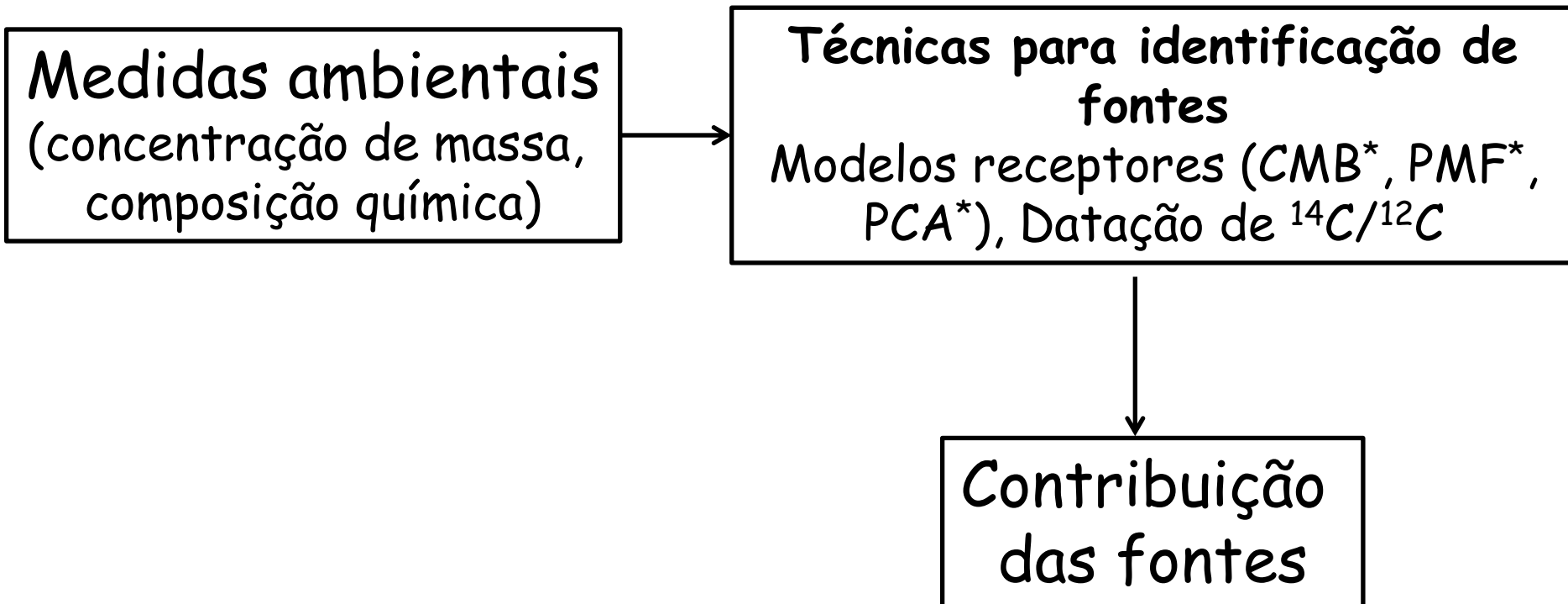
Orgânicos

78%



(Composição média em massa de queimadas na Amazônia)

Fluxograma para identificação e quantificação das fontes de poluentes atmosféricos



* CMB – Carbon Mass Balance

* PMF – Positive Matrix Factorization

* PCA – Principal component analysis

Modelos receptores são utilizado para estimar a contribuição de fontes de emissão atmosférica

Resolver a equação de balanço de massa.

$$x = \sum f_x g + E$$

X =concentração total medida

f =concentração da fonte

E =incerteza da medida

g =fração do poluente na fonte

Seu perfil de emissão é constante.

Exemplos de aplicação de PMF

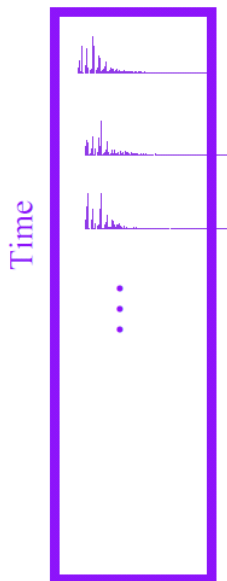
$$X = \sum f \times g + E$$



MP_{2.5}



Data Matrix



=

Contribution (µg/m³), Component 1



Constant Profile, Component 1

Constant Profile, Component 2

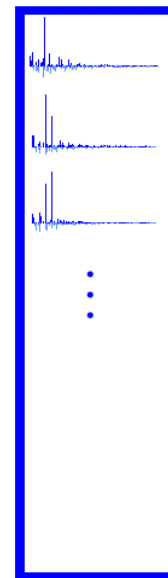
Constant Profile, Component 2



Contribution (µg/m³), Component 2

+ ... +

Residual Matrix



(Ulbrich et al., 2009)

41%

Org

CE 17%

11% Outros

7%

10%

13%

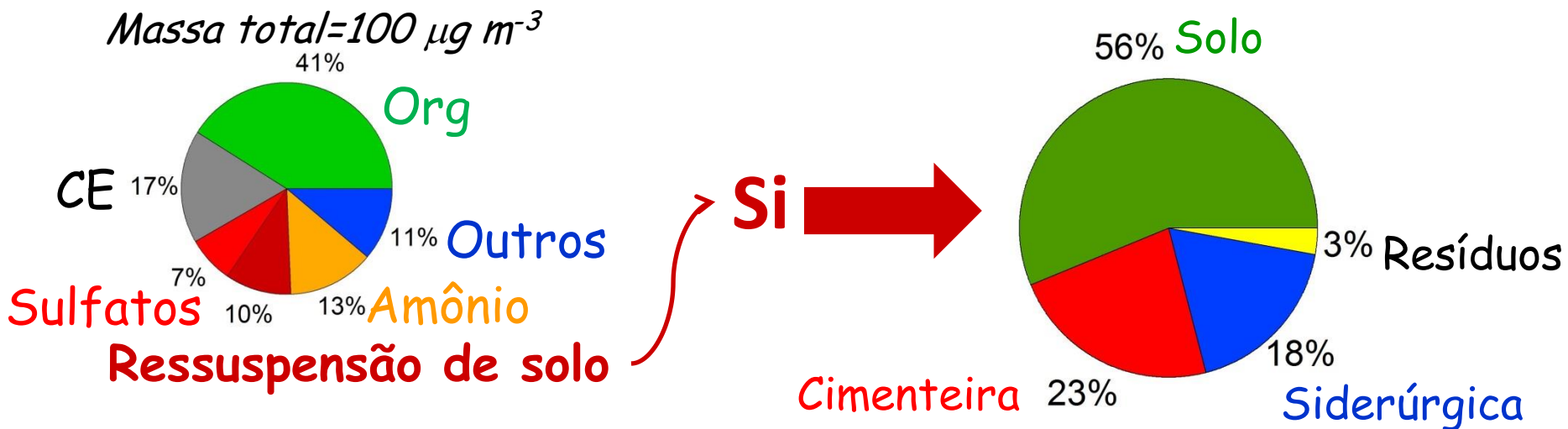
Amônio

Sulfatos

Ressuspensão de solo

Exemplo de aplicação do CMB

Determinação da contribuição das fontes de Si em MP_{10}



$$X = \sum g \times f + E$$

$$Si = G_{Si/solo} \times F_{Solo} + G_{Si/cim} \times F_{cim} + G_{Si/sid} \times F_{sid} + E$$

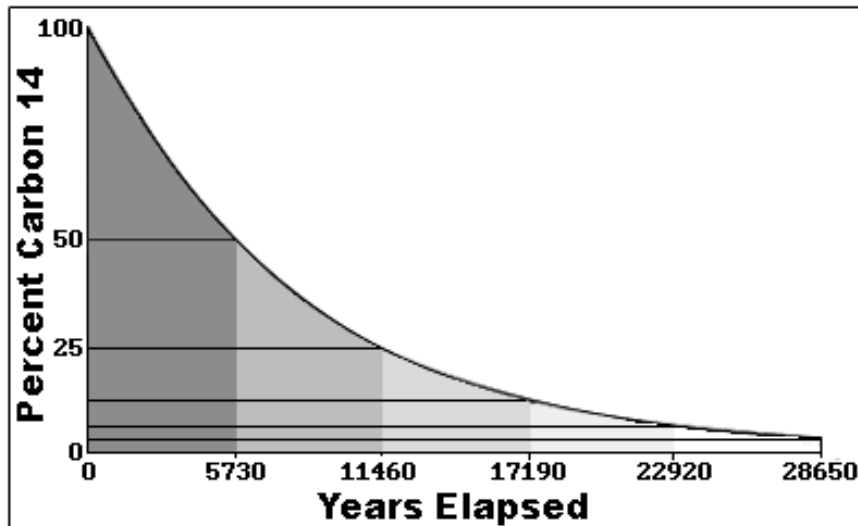
Fração de Si no solo

massa do Solo em MP_{10} (?)

Razão $^{14}\text{C}/^{12}\text{C}$ e $^{13}\text{C}/^{12}\text{C}$

Na natureza as seguintes formas de C coexistem, ^{12}C , ^{13}C (estáveis) e ^{14}C (radioativa).

Permite a diferenciação entre C de origem moderna ou antiga.



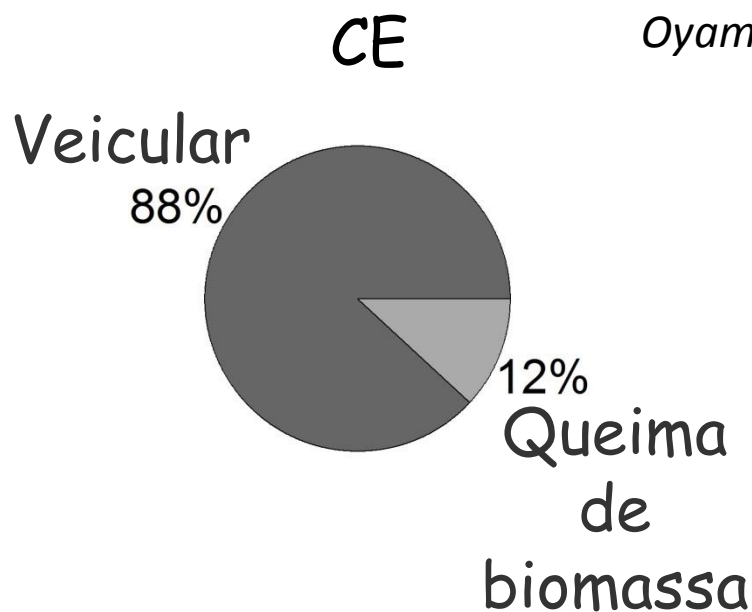
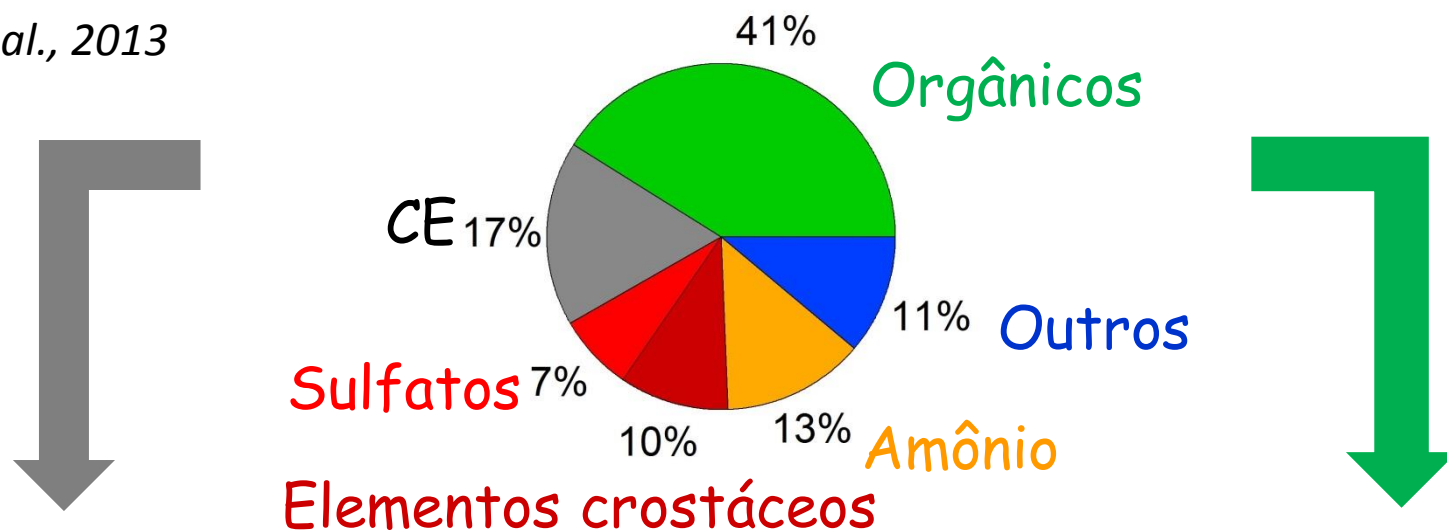
$$F_{14\text{C}} = \frac{^{14}\text{C}/^{12}\text{C} \text{ Amostra}}{^{14}\text{C}/^{12}\text{C} \text{ em } 1950}$$

Exemplos de aplicação em Oyama (2015)

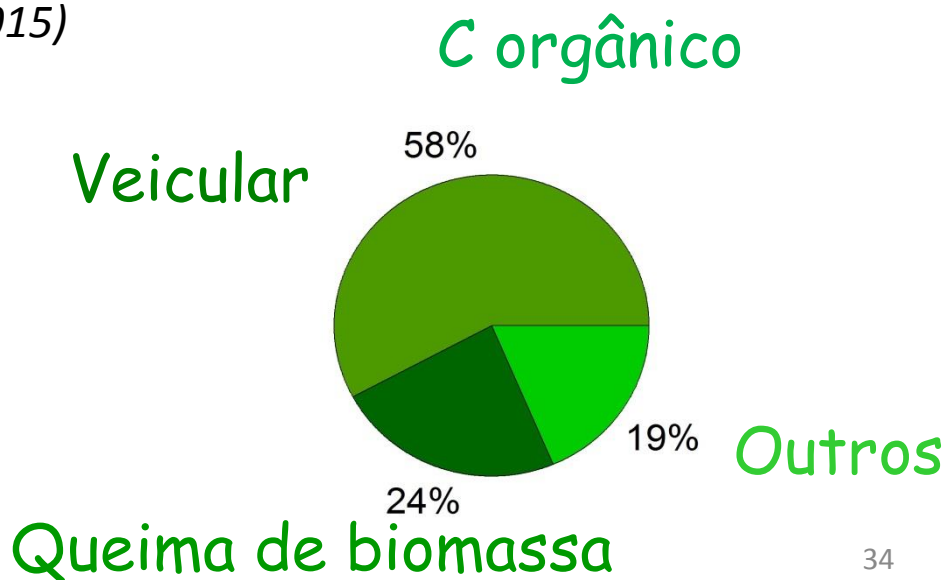
Exemplo de aplicação da razão $^{14}\text{C}/^{12}\text{C}$

Composição média medida em túneis em São Paulo em 2010.

Brito et al., 2013



Oyama (2015)



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Escalas local, regional e global



Global > 2000 Km

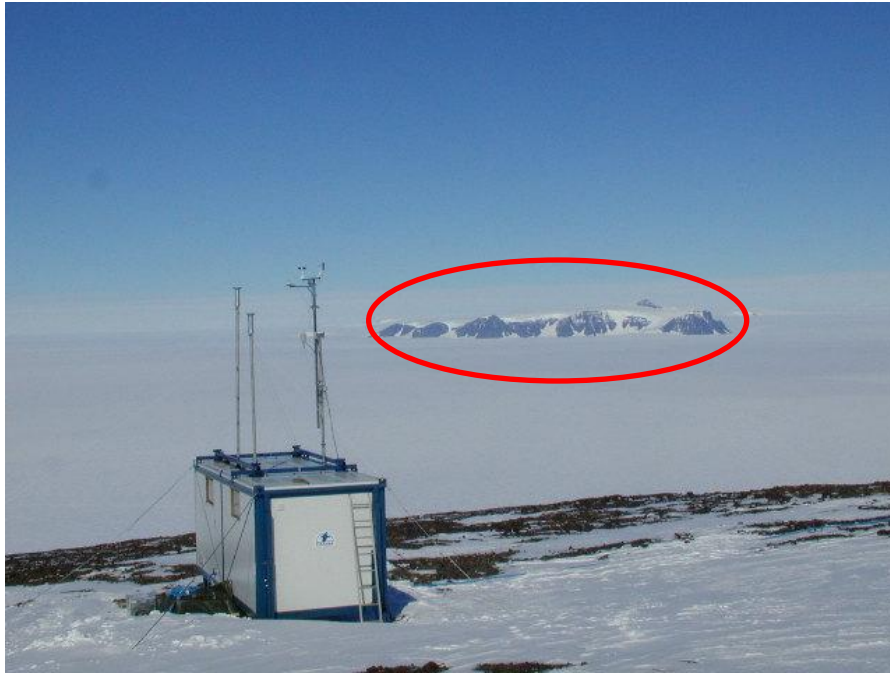


Regional > 200 Km

Local ou urbana < 20 Km



É responsável pela degradação da visibilidade



Antartica > 100 km



Nova Delhi < 1.5 km

Folha exposta à 80 ppb de O₃



Cedida por Marísia - Instituto de Botânica

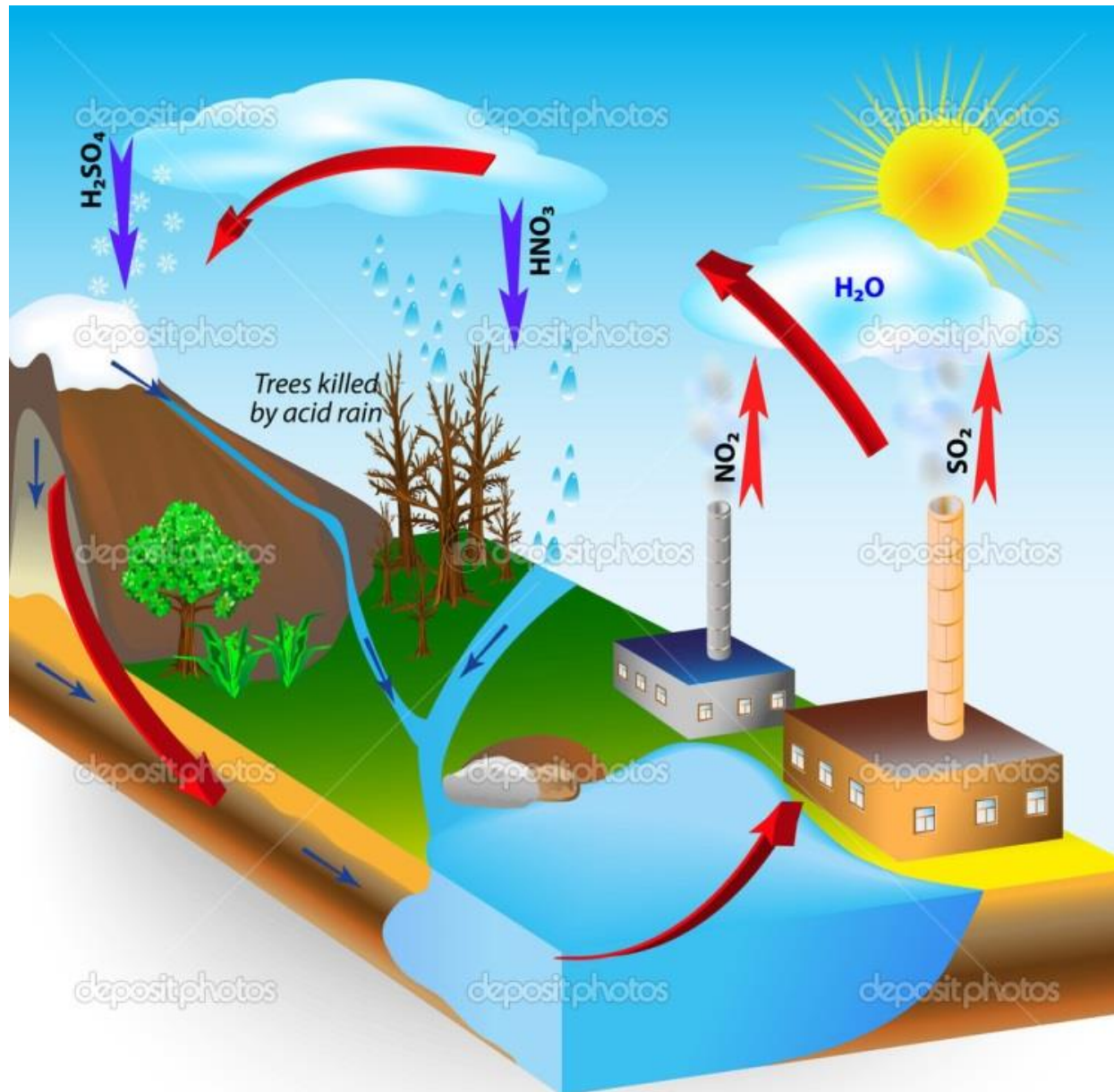
Impactos da poluição do ar: Chuva ácida



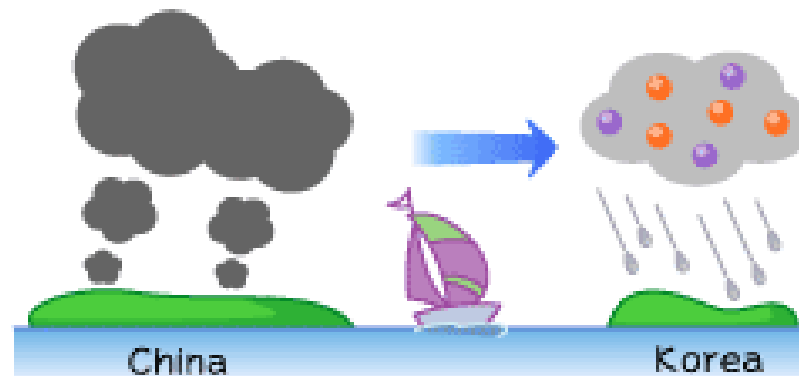
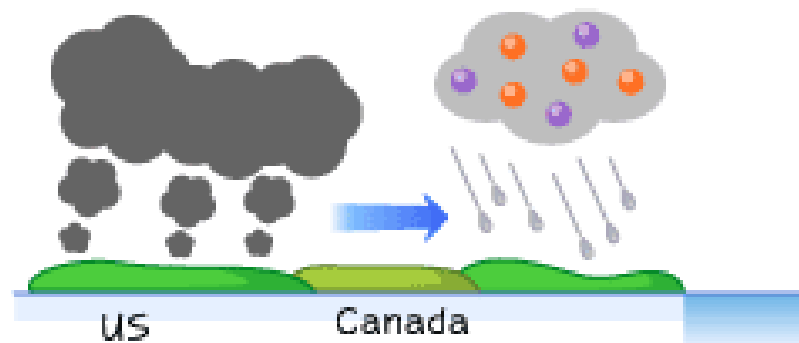
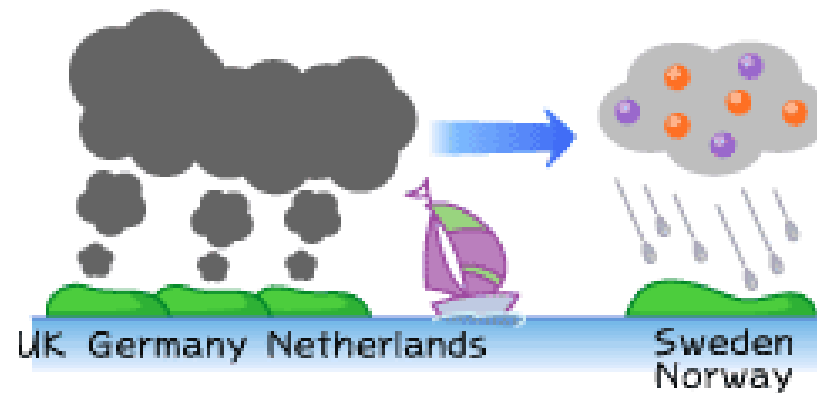
Chuva ácida



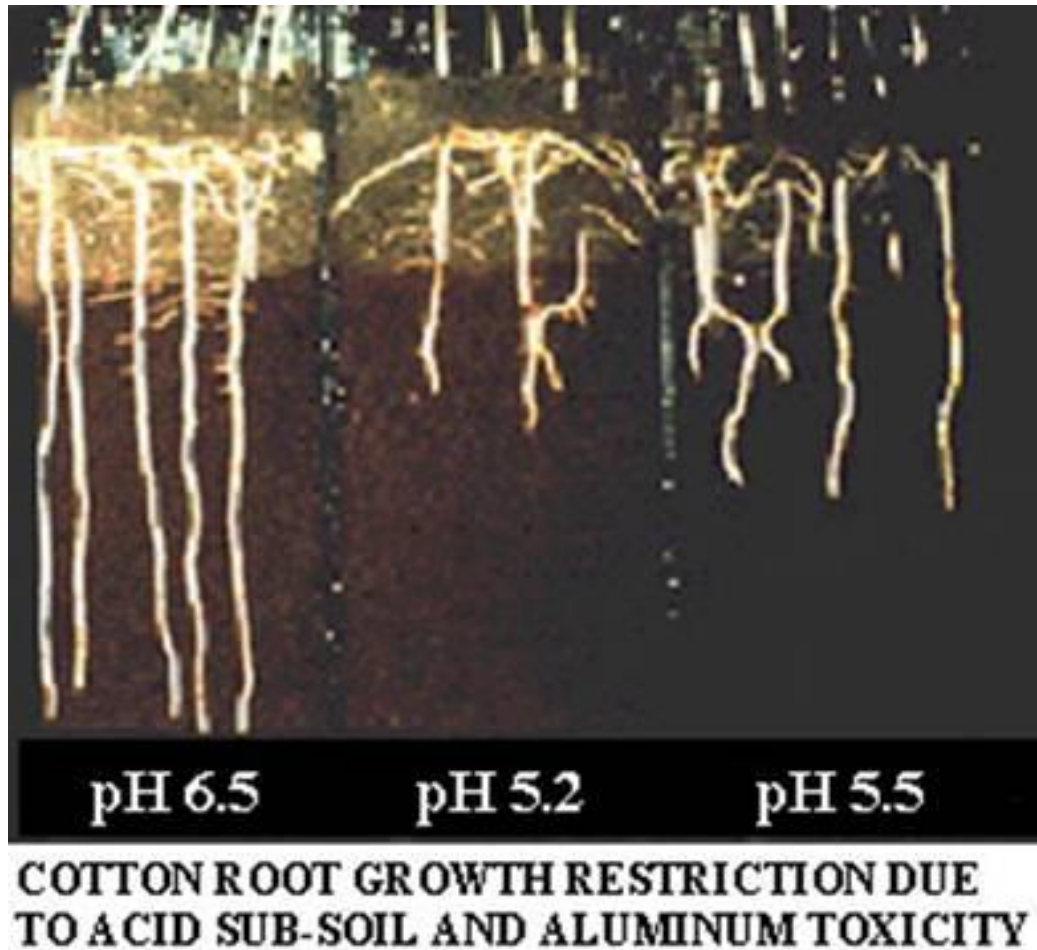
Impactos da poluição do ar: Chuva ácida



Nem sempre os efeitos ocorrem próximo às fontes

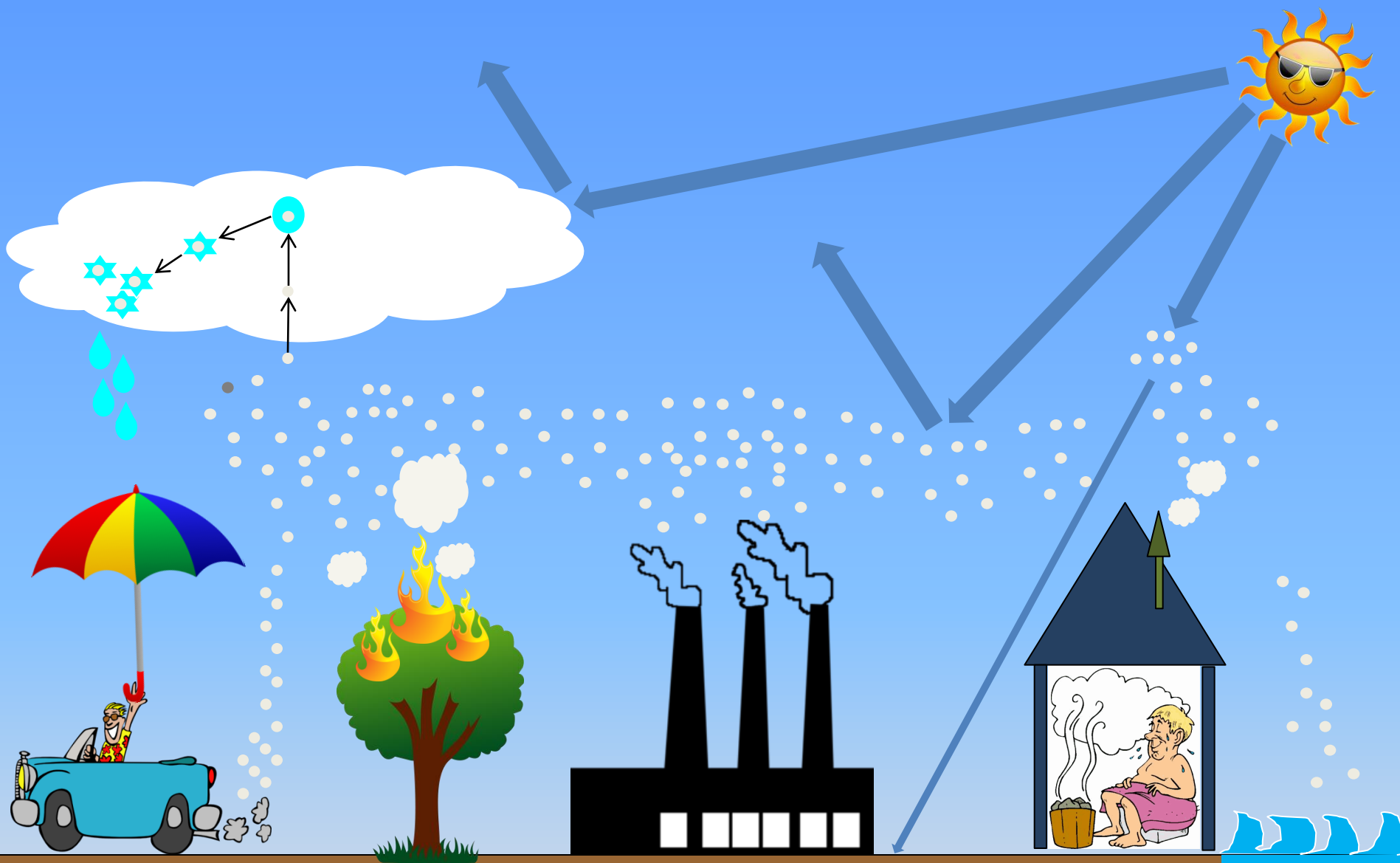


Raízes não se aprofundam no solo acidificado



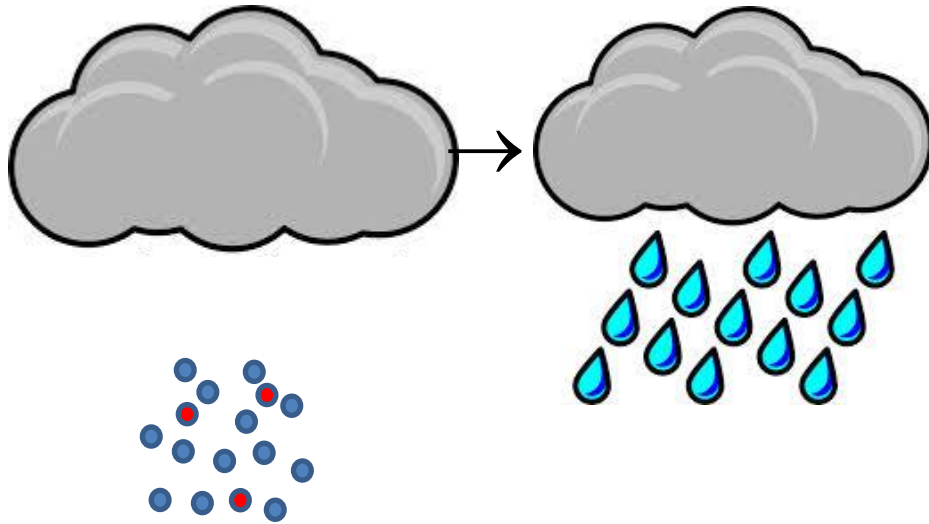
Acidificação do solo ↑ → solubilidade do Al^{3+} ↑

Interação dos poluentes com a radiação solar afeta o balanço radiativo

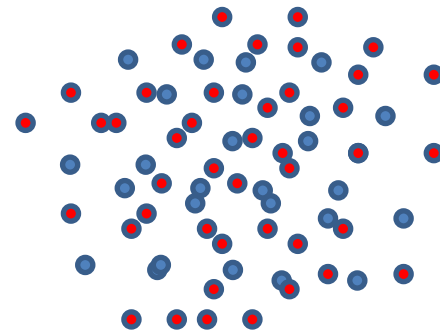


Concentração de aerossóis muito elevadas podem levar a supressão da precipitação

Pouco aerossol
(mais limpo)



Muito aerossol
(muito poluído)



(Competição pelo vapor d'água é maior)

Efeitos na saúde: quanto menor, mais longe vai no organismo

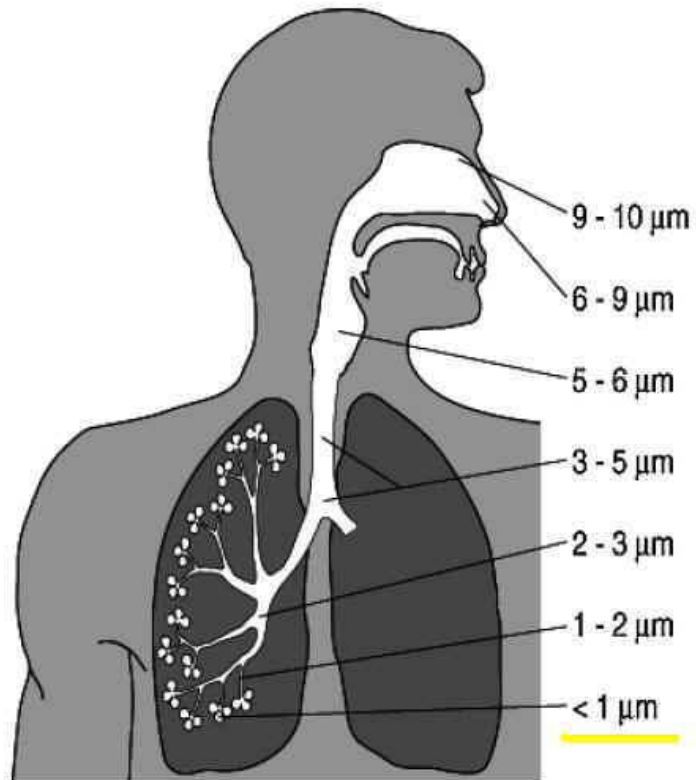
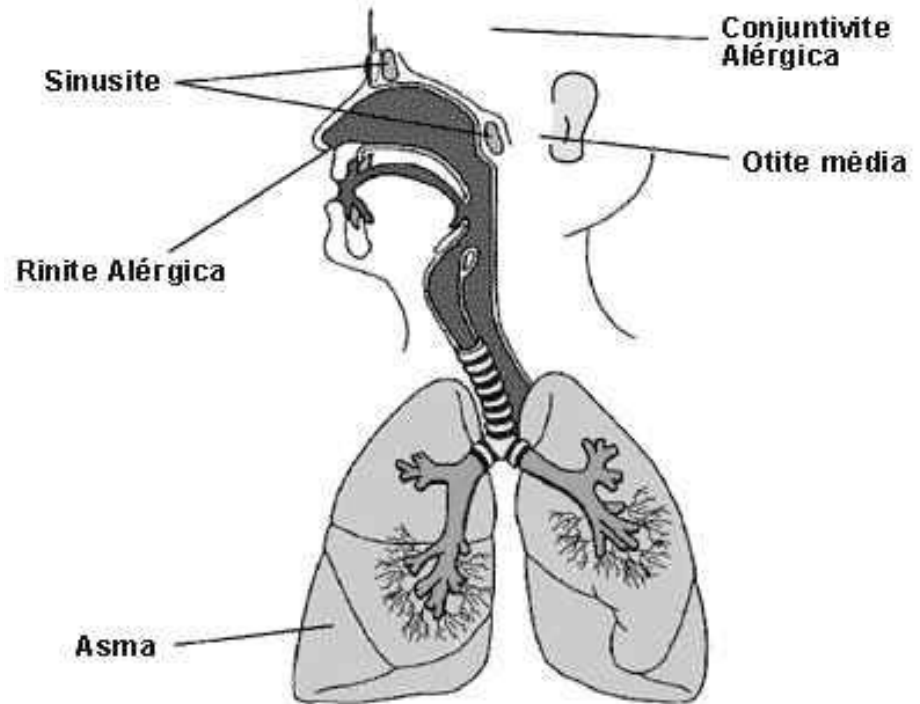


Figure 2 Particle deposition in respiratory system



Mensagens da aula de hoje

- Os poluentes são classificados de acordo com a emissão em primários e secundários ou de acordo com a fonte em naturais e antrópicos.
- A poluição do ar pode ser estudada através de equipamentos de medidas em locais de interesse.
- A forma mais eficiente de mitigar a poluição do ar é identificando as suas fontes.
- Os impactos da poluição do ar ocorrem em todas as escalas degradando a visibilidade, saúde e o meio ambiente.

Bibliografia e leituras recomendadas

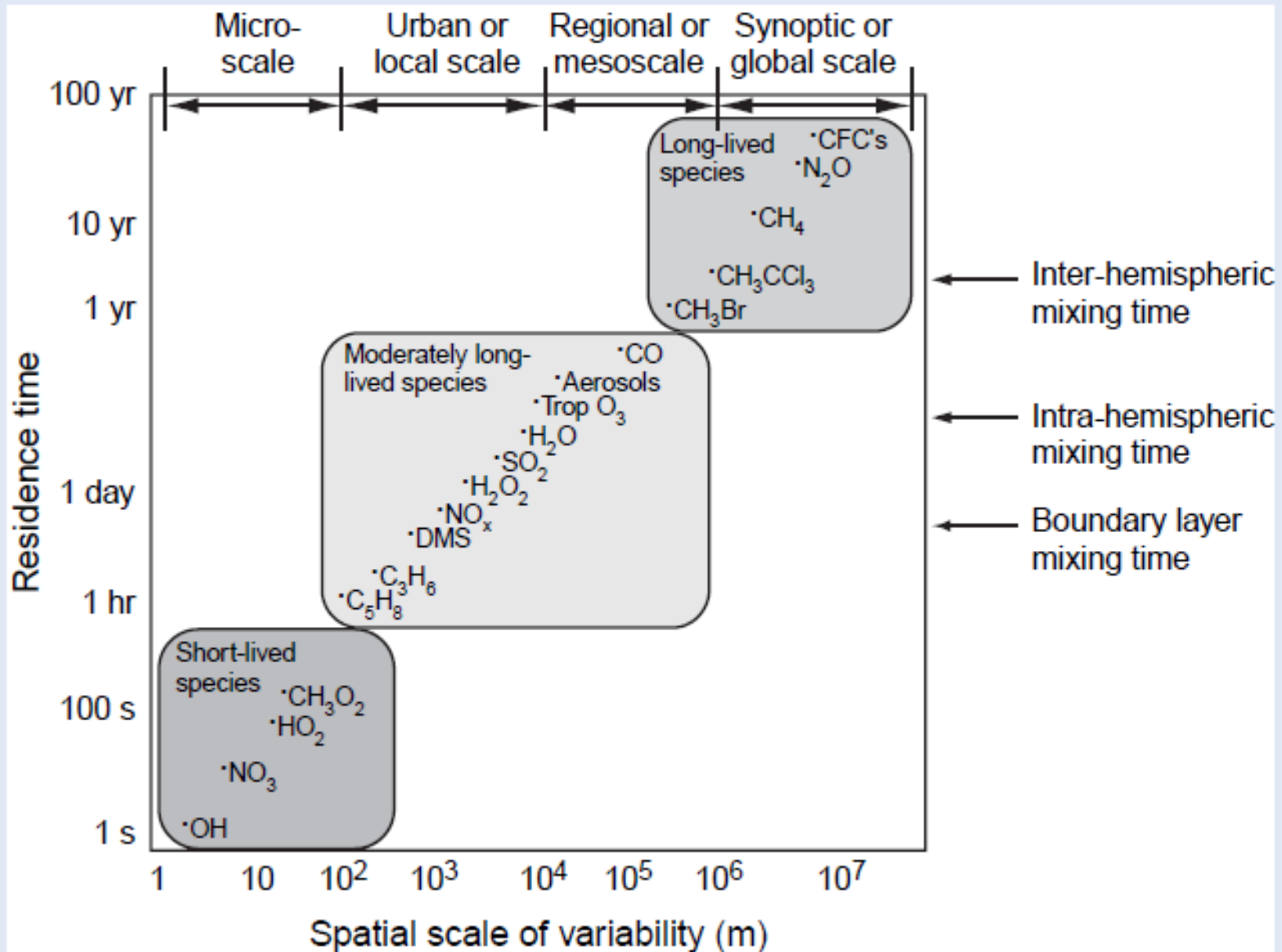
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- 2) Carbone, S., J. F. Brito, L. Xu, N. L. Ng, L. Rizzo, R. Stern, G. Cirino, B. Holanda, E. Senna, S. Wolff, J. Saturno, X. Chi, R. A. F. Souza, A. Arana, M. de Sá, M. Krüger, M. O. Andreae, C. Pöhlker, H. M. J. Barbosa, P. Artaxo: **Long-term chemical composition and source apportionment of submicron aerosol particles in the central Amazon basin (ATTO), in preparation to be submitted to Atmos. Chem. Phys. Discuss.**, 2016.
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Bibliografia e leituras recomendadas

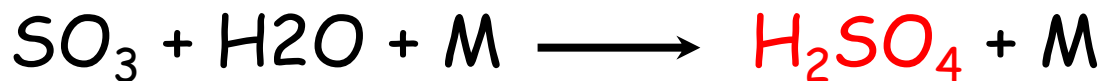
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- 6) Lin, J., Pan, D., Davis, S. J., Zhang, Q., He, K., Wang, C., Streets, D. G., Wuebbles, D. J., Guan, D. **China's international trade and air pollution in the United States.** *PNAS*, 111(5), 1736 - 1741, 2014.
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Slides complementares

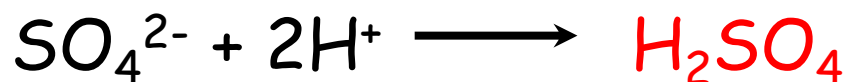
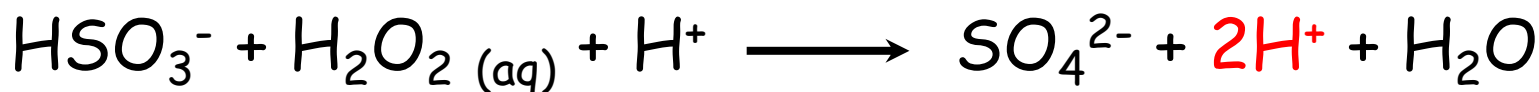
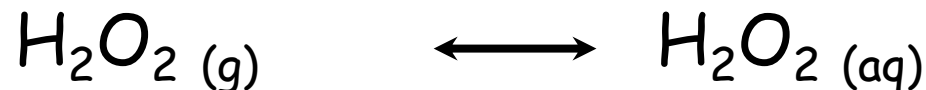
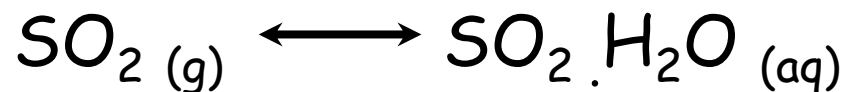
Escalas local, regional e global



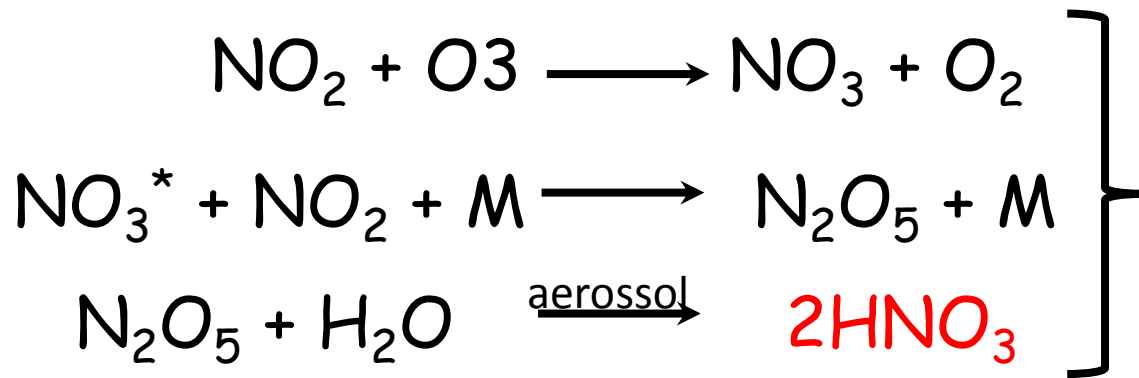
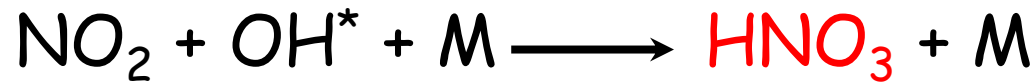
H₂SO₄ e a formação da chuva ácida



SO₂ é dissolvido na água (gota de nuvem ou de chuva) formando ácido sulfúrico



HNO₃ e a formação de chuva ácida



China's international trade and air pollution in the United States

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China is the world's largest emitter of anthropogenic air pollutants, and measurable amounts of Chinese pollution are transported via the atmosphere to other countries, including the United States. However, a large fraction of Chinese emissions is due to manufacture of goods for foreign consumption. Here, we analyze the impacts of trade-related Chinese air pollutant emissions on the global atmospheric environment, linking an economic-emission analysis and atmospheric chemical transport modeling. We find that in 2006, 36% of anthropogenic sulfur dioxide, 27% of nitrogen oxides, 22% of carbon monoxide, and 17% of black carbon emitted in China were associated with production of goods for export. For each of these pollutants, about 21% of export-related Chinese emissions were attributed to China-to-US export. Atmospheric modeling shows that transport of the export-related Chinese pollution contributed 3–10% of annual mean surface sulfate

of GDP in 2006, China emitted 6–33 times as much air pollutants as the United States (Fig. 1 *E–H*). For these reasons, air quality has recently become a major focus of environmental policy in China (8).

In this study, the terms “export,” “import,” and “trade” all refer to transaction of goods between countries. The pollutants emitted in China due to its production of goods for foreign consumption are regarded as emissions embodied in export (EEE) of China (9, 10). The EEE is unique in that the associated goods are consumed outside of China, raising a question about the extent to which China and its export partners should be accountable for the emissions (10–12). The attribution depends on whether the emission accounting is based on production or on consumption. Production-based accounting considers all emissions physically produced in China to be Chinese emissions, in-

 **Leitura recomendada**