Aerossóis, aula 2

Fisica Atmosférica, 2019

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Com slides de HC Hanssen, Peter Tunved, Andre Burger, Marco Franco, etc.

Table 5.3 Estimates (in Tg per year) for the year 2000 of (a) direct particle emissions into the atmosphere and (b) *in situ* production

(a) Direct emissions

	Northern hemisphere	Southern hemisphere
Carbonaceous aerosols		
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Fossil fuel	28	0.4
Biogenic (>1 μm)	–	–
Black carbon (0–2 μm)		
Biomass burning	2.9	2.7
Fossil fuel	6.5	0.1
Aircraft	0.005	0.0004
Industrial dust, etc. (>1 μm)		
Sea salt		
<1 μm	23	31
1–16 μm	1,420	1,870
Total	1,440	1,900
Mineral (soil) dust		
<1 μm	90	17
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Total	1,800	349

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	Northern hemisphere	Southern hemisphere
Sulfates (as NH_4HSO_4)	145	55
Anthropogenic	106	15
Biogenic	25	32
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Nitrate (as NO_3^-)		
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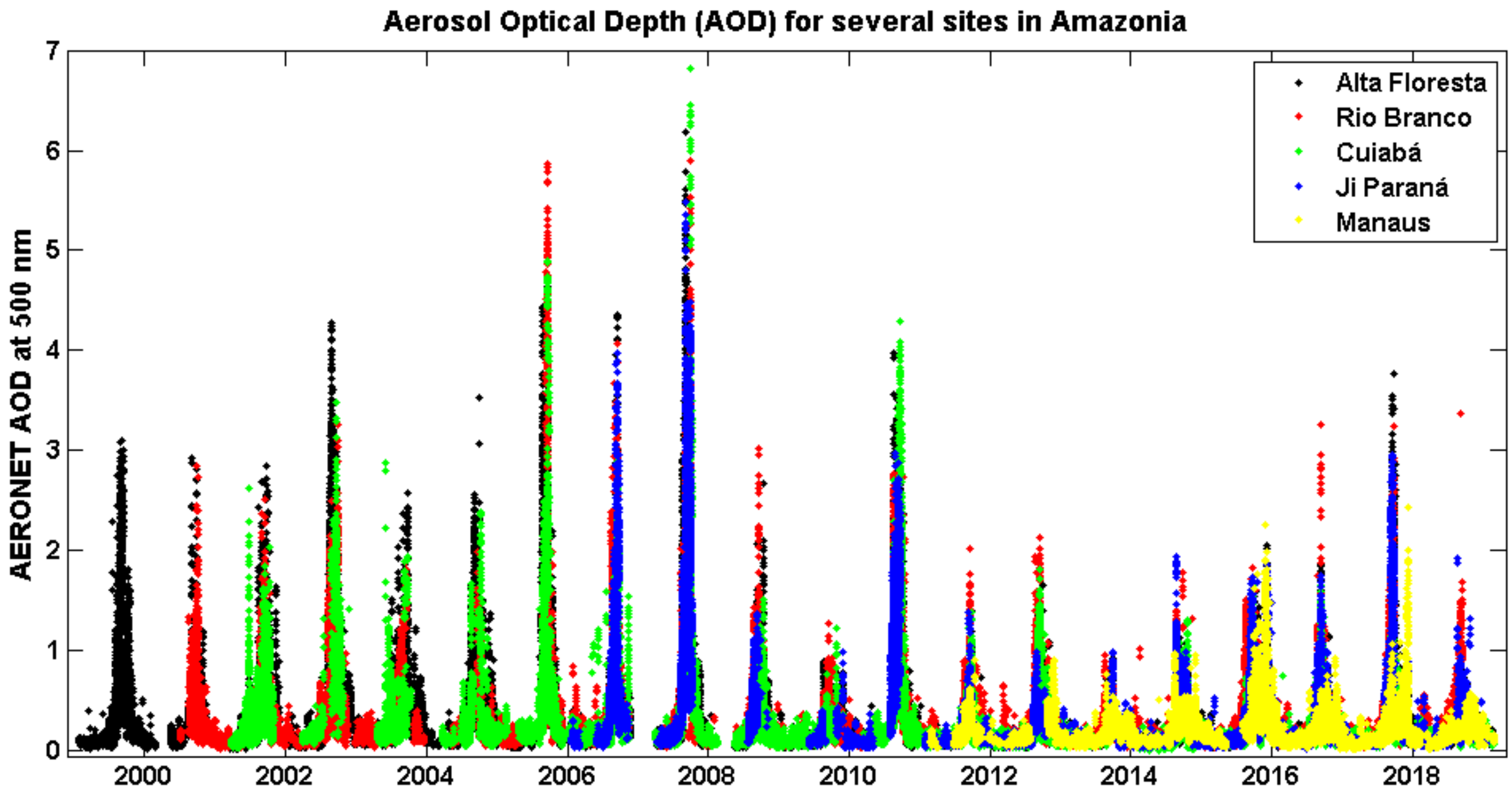
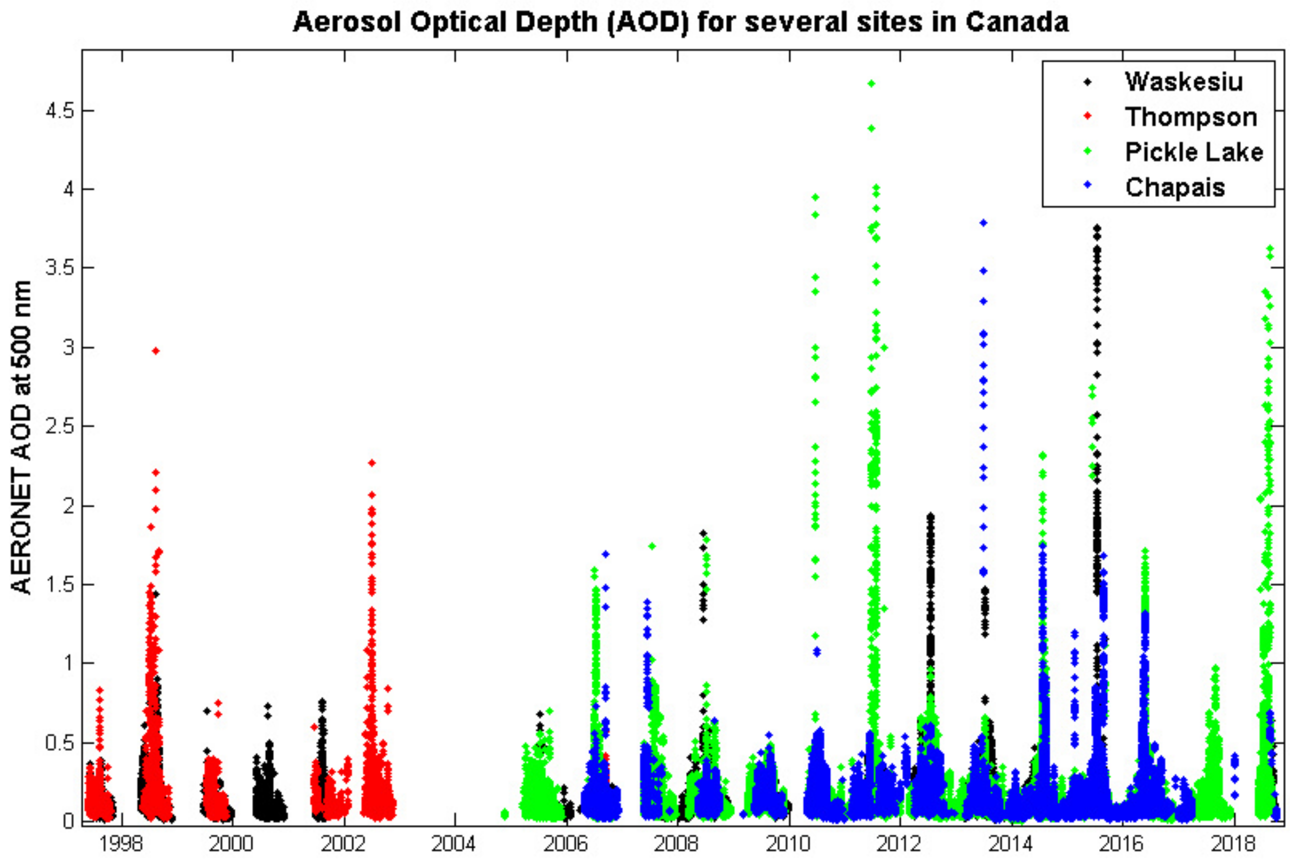
[a] Sizes refer to diameters. [Adapted from Intergovernmental Panel on Climate Change, *Climate Change 2001*, Cambridge University Press, pp. 297 and 301, 2001.]

Queimadas

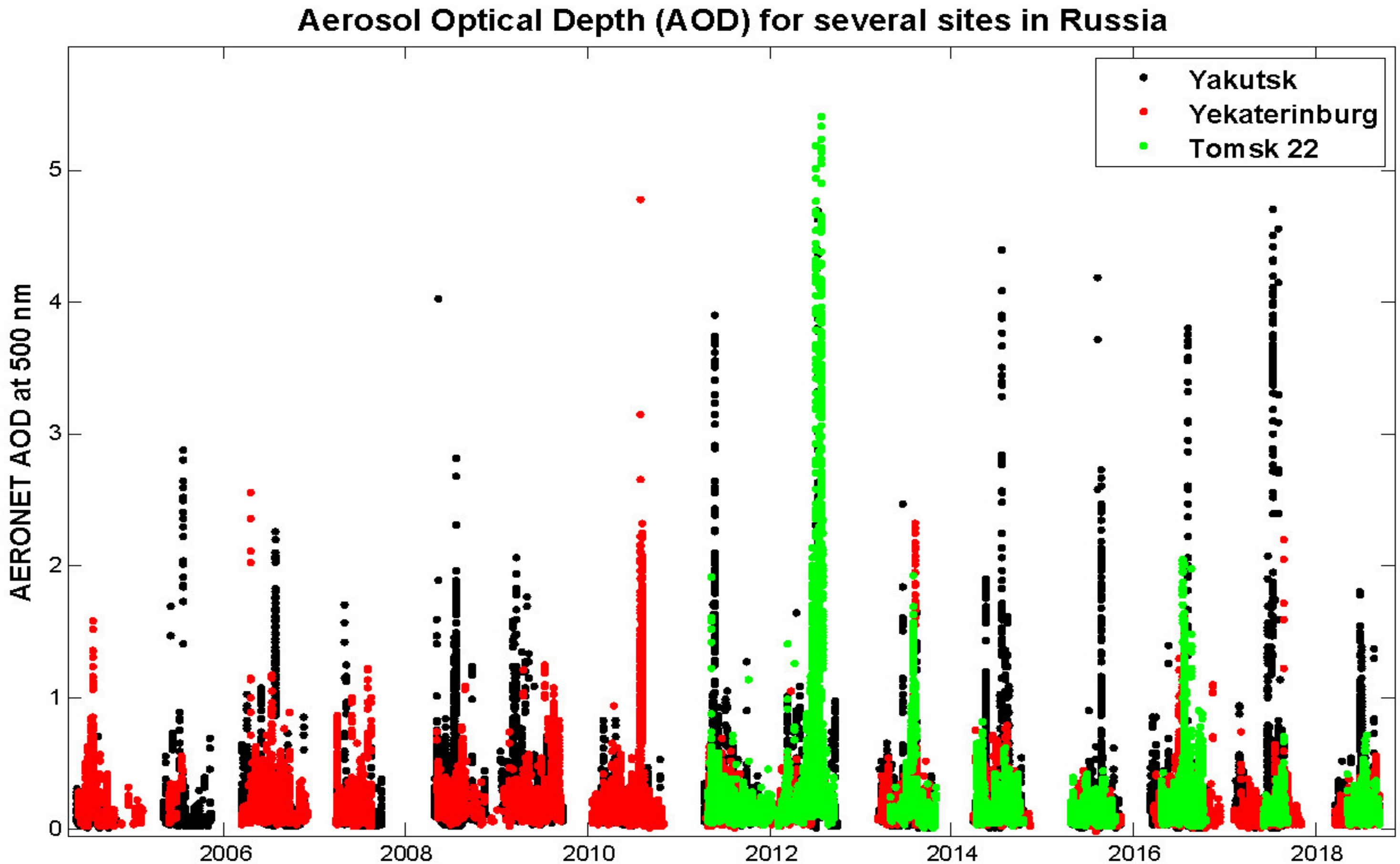
-Time series of AOD for several sites in Amazonia from 2000 to 2019 measured with AERONET sun photometers.

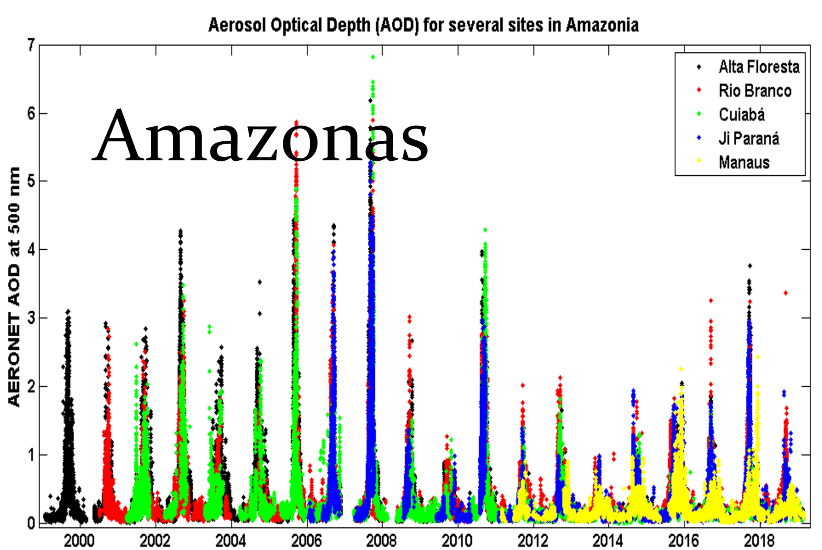


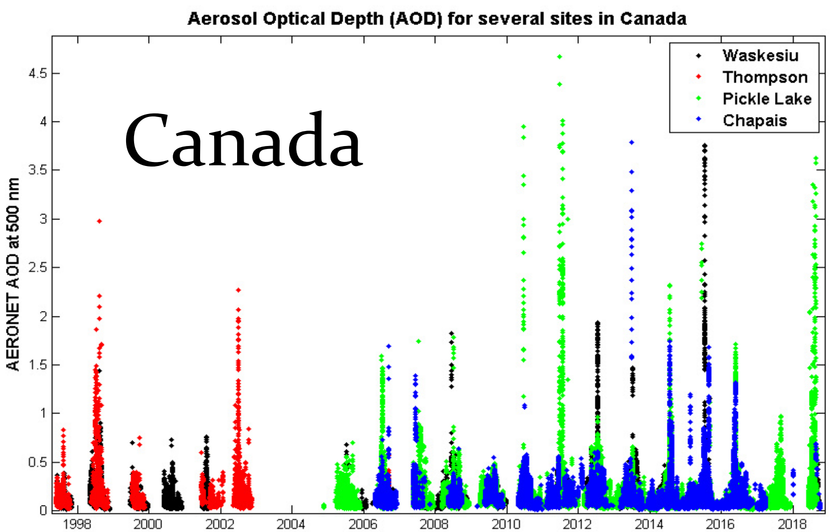
Time series of AOD from 1997 to 2018 for 4 sites in the Canadian boreal forest region: Waskesiu, Thompson, Pickle Lake and Chapais. AOD > 2 were observed during almost all years.

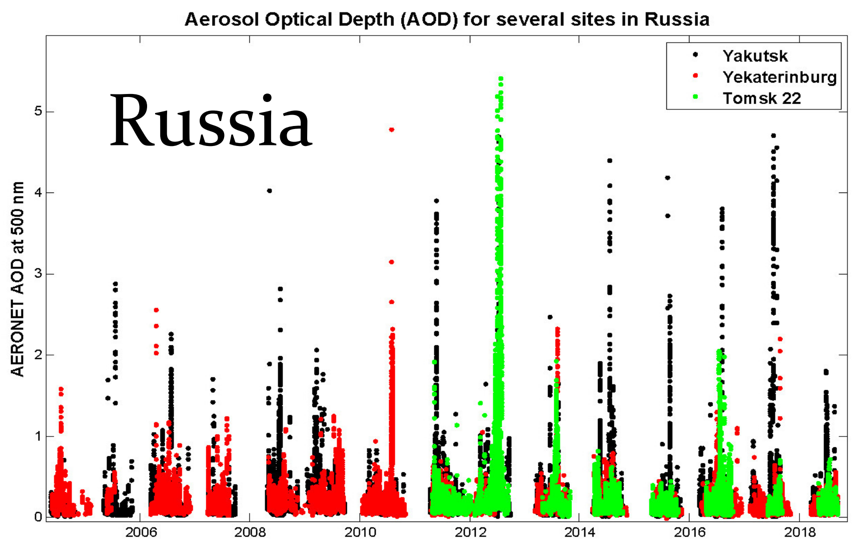


Time series of aerosol optical depth from 2005 to 2018 for 3 AERONET stations over Eurasian Boreal forests: Yakutsk, Yekaterinburg and Tomsk.



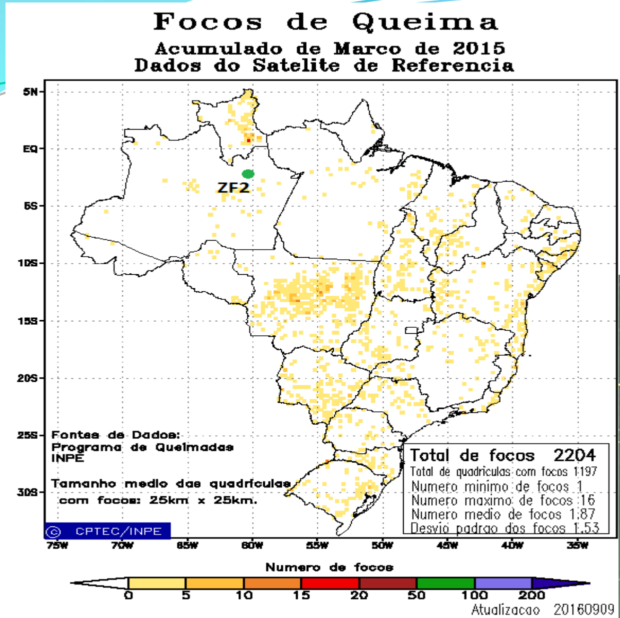




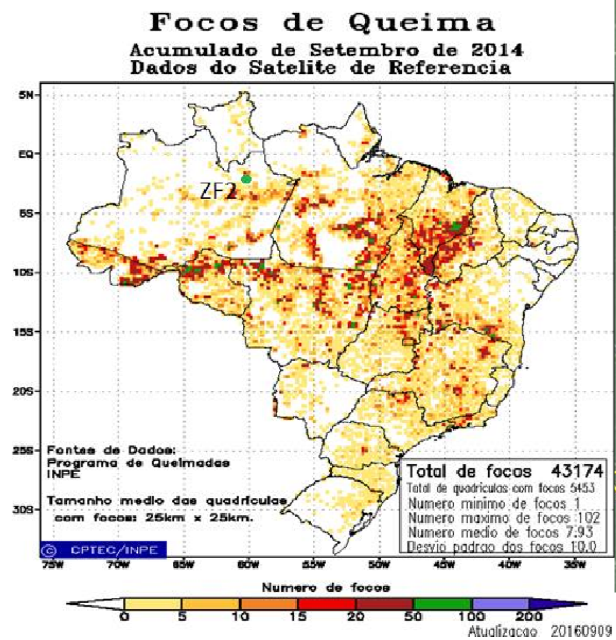


Groundbased AOD measurements from three major forested areas

Queimadas

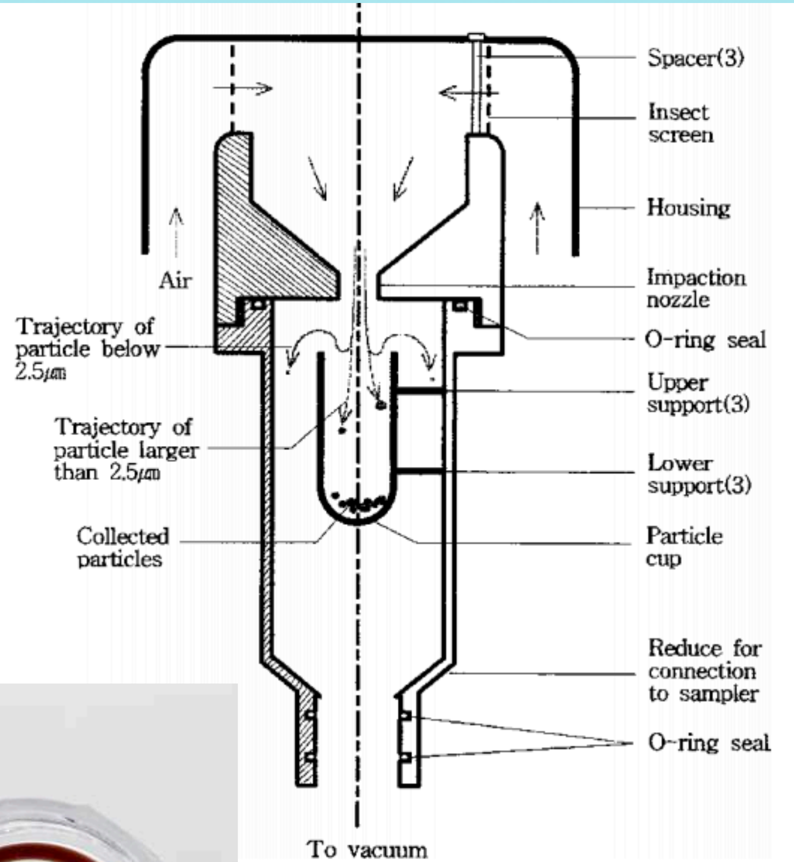


Focos de Queima
Acumulado de Marco de 2015
Dados do Satelite de Referencia
ZF2
Fontes de Dados:
Programa de Queimadas
INPE
Tamanho medio das quadriculas
com focos: 25km x 25km.
CPTEC/INPE
Total de focos 2204
Total de quadriculas com focos 1197
Numero minimo de focos 1
Numero maximo de focos 16
Numero medio de focos 1.87
Desvio padrao dos focos 1.53
Numero de focos
0 5 10 15 20 50 100 200
Atualizacao 20160909



Focos de Queima
Acumulado de Setembro de 2014
Dados do Satelite de Referencia
ZF2
Fontes de Dados:
Programa de Queimadas
INPE
Tamanho medio das quadriculas
com focos: 25km x 25km.
CPTEC/INPE
Total de focos 43174
Total de quadriculas com focos 5453
Numero minimo de focos 1
Numero maximo de focos 102
Numero medio de focos 7.93
Desvio padrao dos focos 10.0
Numero de focos
0 5 10 15 20 50 100 200
Atualizacao 20160909

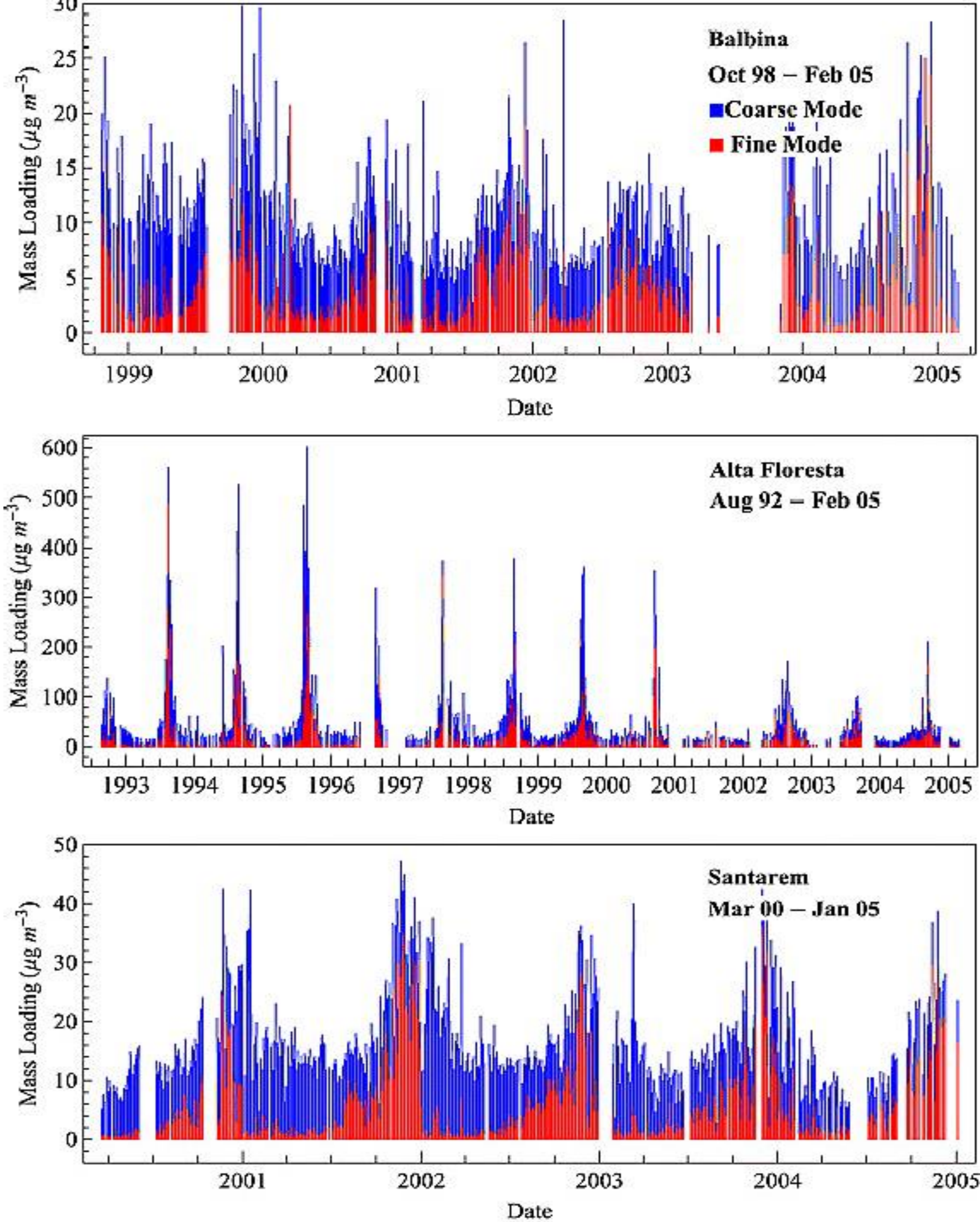
Roraima
Berbice Oriental-Corentyne
Amapá
Balbina
Pará
Santarém
Manaus
Amazonas
Brasil
Alta Floresta
Alta Floresta
Tocantins
Rondônia
558 km
US Dept of State Geographer
© 2018 Google
Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Mato Grosso
Google Earth



re 1. Schematic diagram of the $PM_{2.5}$ inlet.

Concentração de Aerossol na Amazônia

- Sítio Balbina:
  - pouca influência de aerossóis de queimada;
  - PM_{10} ~11µg/m³, com $PM_{2,5}$ variando entre 2µg/m³ (chuvosa) e 4µg/m³ (seca);
- Sítio Alta Floresta:
  - localizada em região de queimadas:
  - PM_{10} variando entre 9 e 12µg/m³ (chuvosa) e 300-600µg/m³ (seca);
  - Picos de PM ocorrem durante o último bimestre do ano;
- Santarém:
  - PM_{10} sobe de ~10µg/m³ (chuvosa) para ~40µg/m³ (seca);/
  - Picos de PM no 3º bimestre;



CETESB

Qualidade do Ar

SÃO PAULO GOVERNO DO ESTADO

Sao Paulo

Dados Horários

Índice de Qualidade	0 - 40	41 - 80	81 - 120	121 - 200	> 200
Classificação	N1 - Boa	N2 - Moderada	N3 - Ruim	N4 - Muito Ruim	N5 - Péssima

Pinheiros - 24/09/2019

Hora	NO2 µg/m³		MP10 µg/m³			CO ppm			O3 µg/m³			MP2.5 µg/m³			BENZENO ug/m3	TOLUENO ug/m3
	Média Horária	Índice / Qualidade	Média horária	Média 24 h	Índice / Qualidade	Média horária	Média 8 h	Índice / Qualidade	Média horária	Média 8 h	Índice / Qualidade	Média horária	Média 24 h	Índice / Qualidade	Média Horária	Média Horária
01:00	6	1	7	--	--	0.1	0,2	1	30	33	13	3	5	8	0,0	0,1
02:00	4	1	4	--	--	0.1	0,2	1	38	34	14	--	6	9	0,1	0,1
03:00	3	0	8	17	13	0.1	0,2	1	40	35	14	3	5	8	0,0	0,2
04:00	2	0	9	16	13	0.1	0,1	1	43	37	15	2	5	8	0,0	0,1
05:00	3	0	15	16	13	0.1	0,1	1	40	37	15	--	5	8	0,0	0,1
06:00	6	1	18	16	13	0.2	0,1	1	31	36	14	5	5	8	0,0	0,0
07:00	9	2	22	17	13	0.3	0,2	1	25	35	14	9	6	9	0,0	0,0
08:00	11	2	29	17	13	0.4	0,2	1	20	33	13	12	6	9	0,0	0,1
09:00	12	2	21	17	13	0.5	0,2	1	20	32	13	13	6	9	0,0	0,1
10:00	10	2	39	18	14	0.4	0,3	1	25	30	12	16	7	11	0,0	0,1
11:00	10	2	28	19	15	0.4	0,3	1	31	29	12	19	7	11	0,0	0,3
12:00	13	3	27	19	15	0.5	0,3	2	42	29	12	17	8	13	0,2	1,9
13:00	15	3	45	20	16	0.5	0,4	2	76	34	14	20	9	14	0,1	0,9
14:00	14	3	33	21	17	0.4	0,4	2	81	40	16	19	9	14	0,1	1,0
15:00	14	3	36	22	17	0.3	0,4	2	64	45	18	19	10	16	0,2	1,3
16:00	16	3	46	22	17	0.4	0,4	2	56	49	20	21	11	17	0,1	1,6
17:00	15	3	39	23	18	0.4	0,4	2	41	52	21	21	11	17	0,1	5,6
18:00	16	3	29	23	18	0.4	0,4	2	27	52	21	16	12	19	0,1	2,3
19:00	18	4	33	24	19	0.5	0,4	2	9	50	20	15	12	19	0,1	0,9
20:00	11	2	26	24	19	0.3	0,4	2	22	47	19	17	12	19	0,1	0,4
21:00	13	3	21	24	19	0.4	0,4	2	18	40	16	15	13	20	0,0	0,1
22:00	10	2	31	25	20	0.3	0,4	2	24	33	13	13	13	20	0,0	0,3
23:00	9	2	23	25	20	0.3	0,4	2	25	28	11	17	14	22	0,0	0,2
24:00	7	2	27	26	21	0.3	0,4	2	32	25	10	15	14	22	0,1	0,2

Cidade de Porto Velho sob intensa fumaça de queimadas — Foto: Renata Silva/ Arquivo Pessoal

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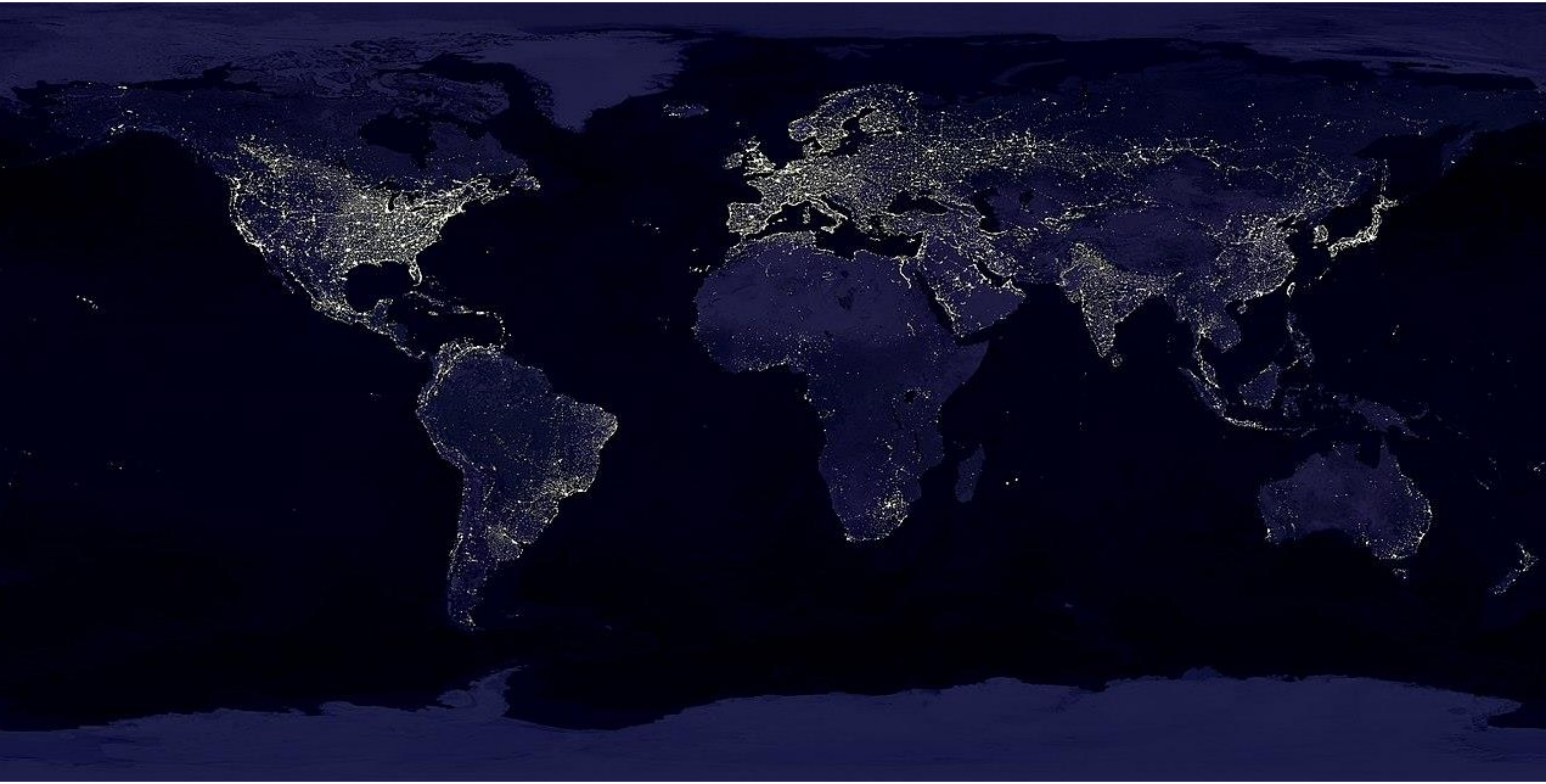
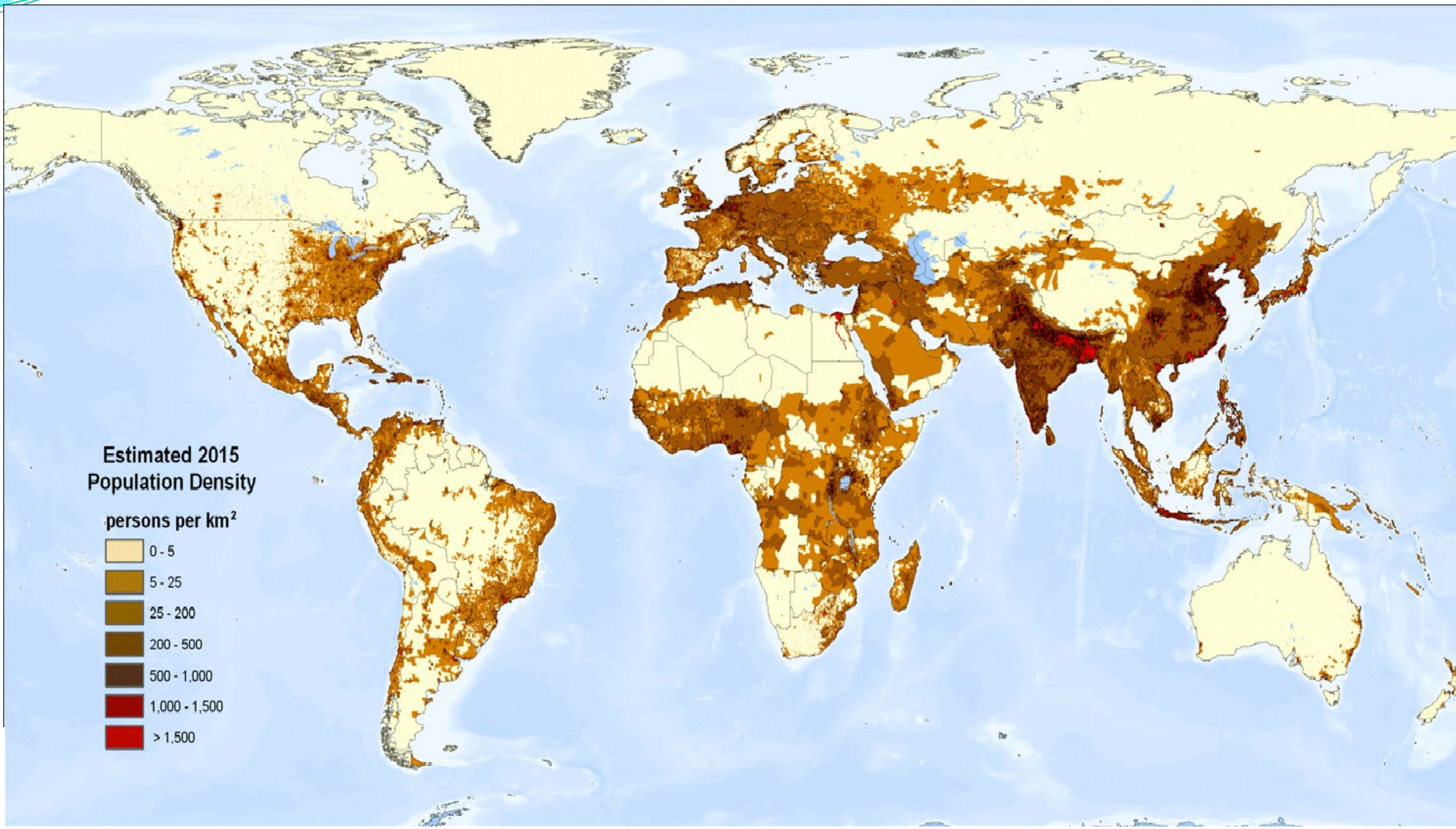
As cidades



Luzes das cidades podem ser vistas nesta montagem de imagens da Terra à noite, fotografadas por satélites da NASA.

As cidades



Population density (people per km^2) map of the world in 2015. In relation to the equator it is seen that the vast majority of the human population lives in the Northern Hemisphere

As cidades

- Áreas mais densamente povoadas do mundo;

- A ONU estima que, até 2030, 9% da população esteja morando em megacidades (aquelas com mais de 10mi de habitantes);

- São Paulo é a cidade mais populosa do Brasil e de todo o hemisfério sul com ~12mi de habitantes e ~7mi de veículos (IBGE);

Os aerossóis urbanos

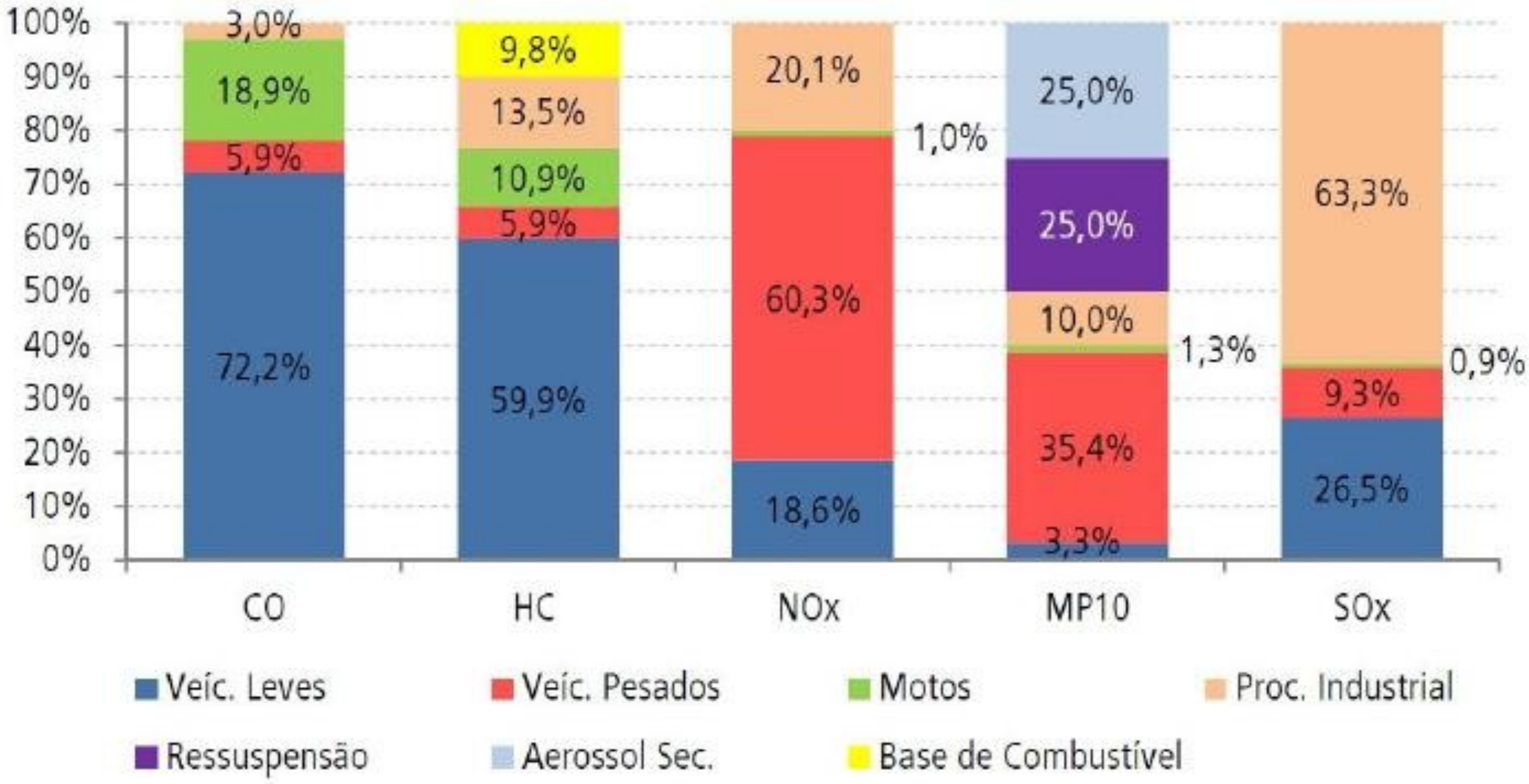


Figura 1-7 – Estimativas de emissão relativa dos diversos poluentes por tipos de fontes. São consideradas emissões de veículos leves e pesados, bem como motocicletas, processos industriais, ressuspensão de solo, formação de aerossol orgânico secundário e finalmente emissões de bases distribuidoras de combustíveis líquidos. Fonte: (CETESB, 2012).

Os aerossóis urbanos

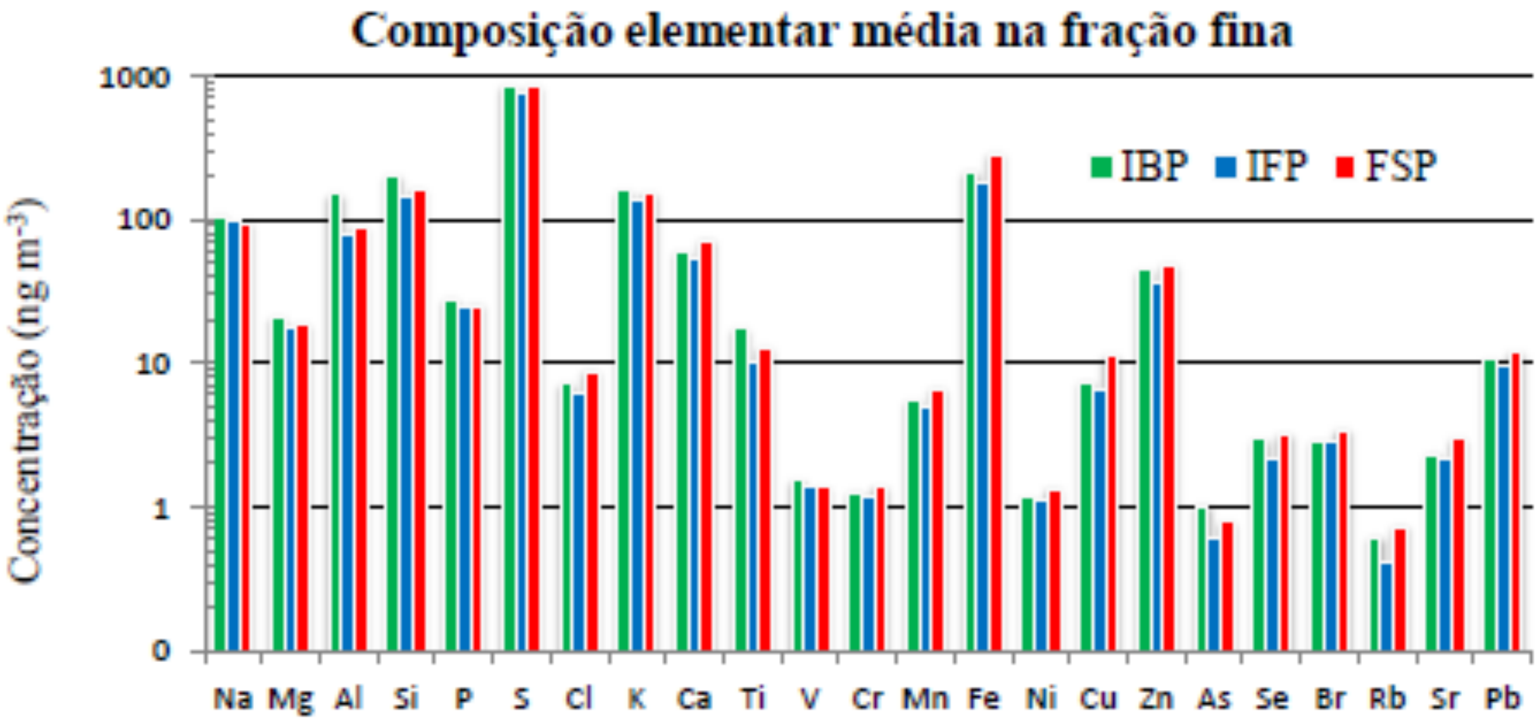


Figura 4-9 Concentrações elementares médias identificadas na moda fina em IBP, IFP e FSP por XRF. Gráfico em escala logarítmica.

Os aerossóis urbanos

PM2,5

	Ibirapuera		IFUSP		Cerqueira César	
Componente	%	σ	%	σ	%	σ
Aerossol Orgânico (OM)	42	15	58	31	45	14
EC	16	7	27	20	22	9
Amônia	7.4	5.4	8	4	7.9	4.6
Nitrato	0.9	0.8	1.3	0.7	1.1	0.7
Sulfato	23	13	24	11	22	10
Aerossol Marinho	1.5	1.0	1.6	1.0	1.5	1.1
Poeira de Solo	12	7	11	4	13	5
Elementos Traço	1.3	1.2	1.4	1.2	1.5	1.1
Soma	104	50	132	72	114	45

Tabela 4-7- Atribuição percentual média da massa gravimétrica aos diferentes tipos de aerossol para o material particulado fino nas estações Ibirapuera, IFUSP e Cerqueira César, onde σ é o desvio padrão associado.

PM2,5-10

Sem componente orgânica!

	Ibirapuera		IFUSP		Cerqueira César	
Componente	%	σ	%	σ	%	σ
EBC	2.1	0.7	2.4	0.8	2.6	0.8
Amônia	0.4	0.6	0.4	0.5	0.5	0.5
Nitrato	3.9	2.3	5.7	3.2	4.7	2.5
Sulfato	4.6	3.2	5.8	2.7	5.8	2.7
Aerossol Marinho	2.8	3.9	3.6	4.3	3.2	3.9
Poeira de Solo	38	17	39	7	40	6
Elementos Traço	2.5	0.9	2.4	0.9	2.7	0.9
Soma	54	29	59	19	59	17

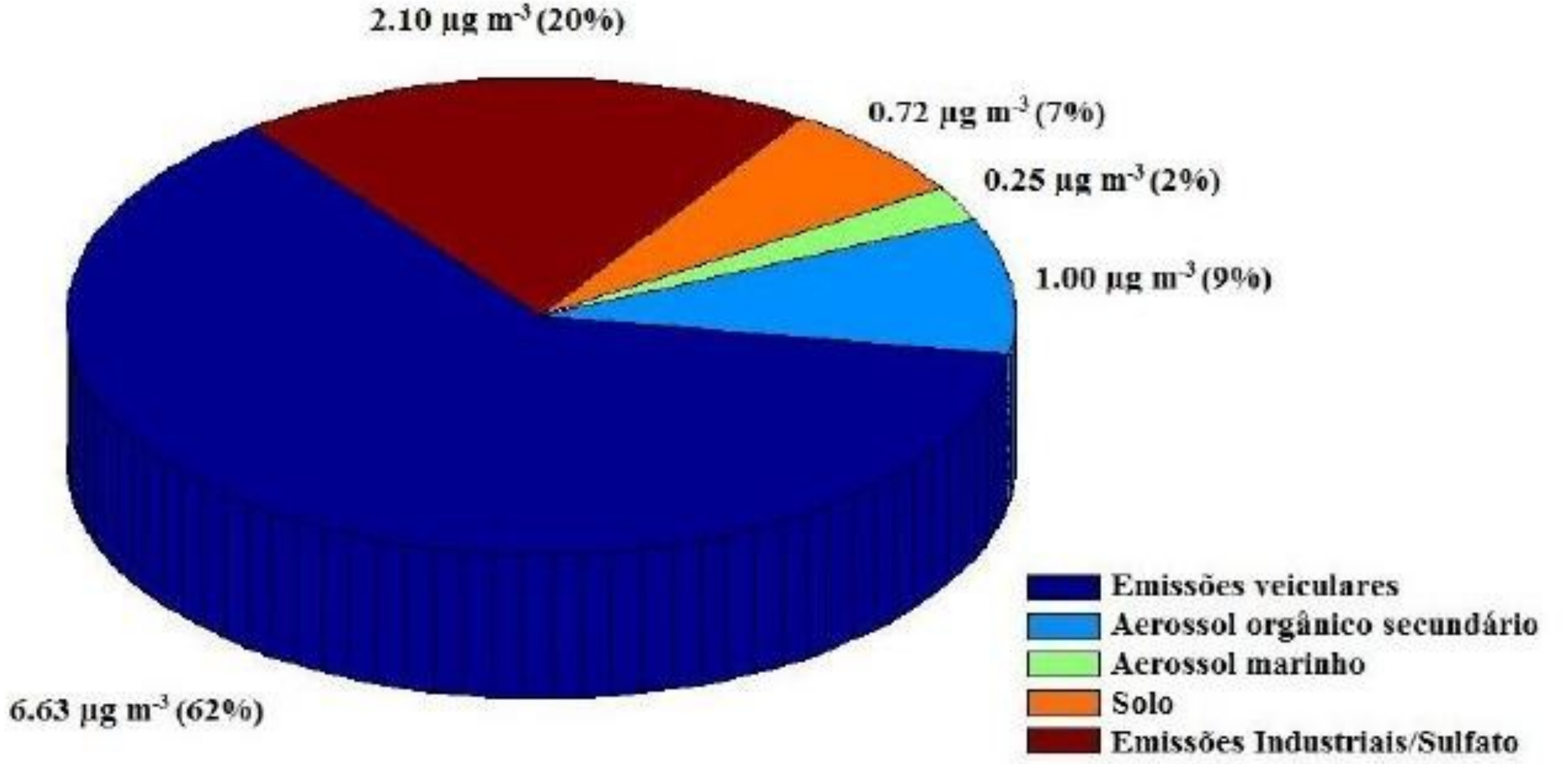
Tabela 4-8- Atribuição percentual média da massa gravimétrica aos diferentes tipos de aerossol para o material particulado grosso nas estações Ibirapuera, IFUSP e Cerqueira César, onde σ é o desvio padrão associado.

Os aerossóis urbanos – Contribuição de diferentes processos

Estação amostradora	Emissões Veiculares	Sulfato + Indústrias	Ressuspensão de Solo	Aerossol Marinho	Aerossol Org Secundário
Ibirapuera	67%	15%	9%	4%	5%
IFUSP	63%	18%	7%	5%	7%
C. César	60%	21%	12%	5%	2%
Média	**63%**	**18%**	**9%**	**5%**	**5%**

Tabela 5-4 – Compilação geral dos resultados obtidos para a atribuição de fontes de $PM_{2,5}$ nas estações amostradoras do Ibirapuera, IFUSP e Cerqueira César.

Os aerossóis urbanos – Identificação de processos



5-4 Atribuição final de fontes do material particulado fino para o conjunto de dados
es IFUSP, Cerqueira César e Ibirapuera.

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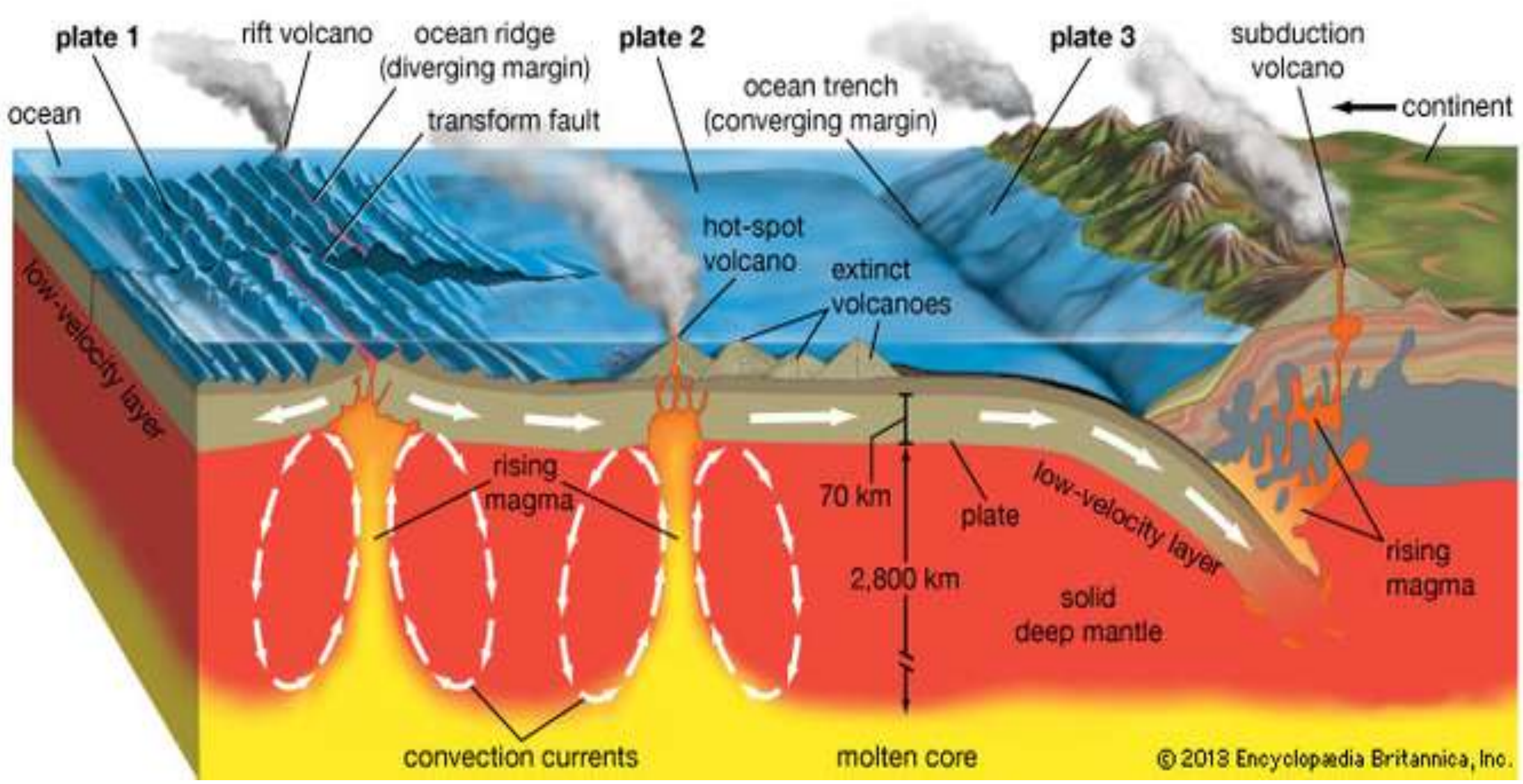
Volcanism

Data (before Industrial Era): analysis of acidity and sulfate measured in ice cores and catalogues of volcanic eruptions;

- Evidences of ~2000 years ago: Mount Etna dimmed the Sun what may have resulted in cooling -> shriveling crop -> famine in Rome and Egypt;
- Benjamin Franklin: Lakagigar eruption (1783) might have been responsible for abnormally cold summer of 1783 in Europe and the cold winter of 1783-84;
- Humphreys (1913): first association of cooling events after large volcanic eruptions with radiative effects of the stratospheric aerosols;

Robock, A., 2000

Volcanism



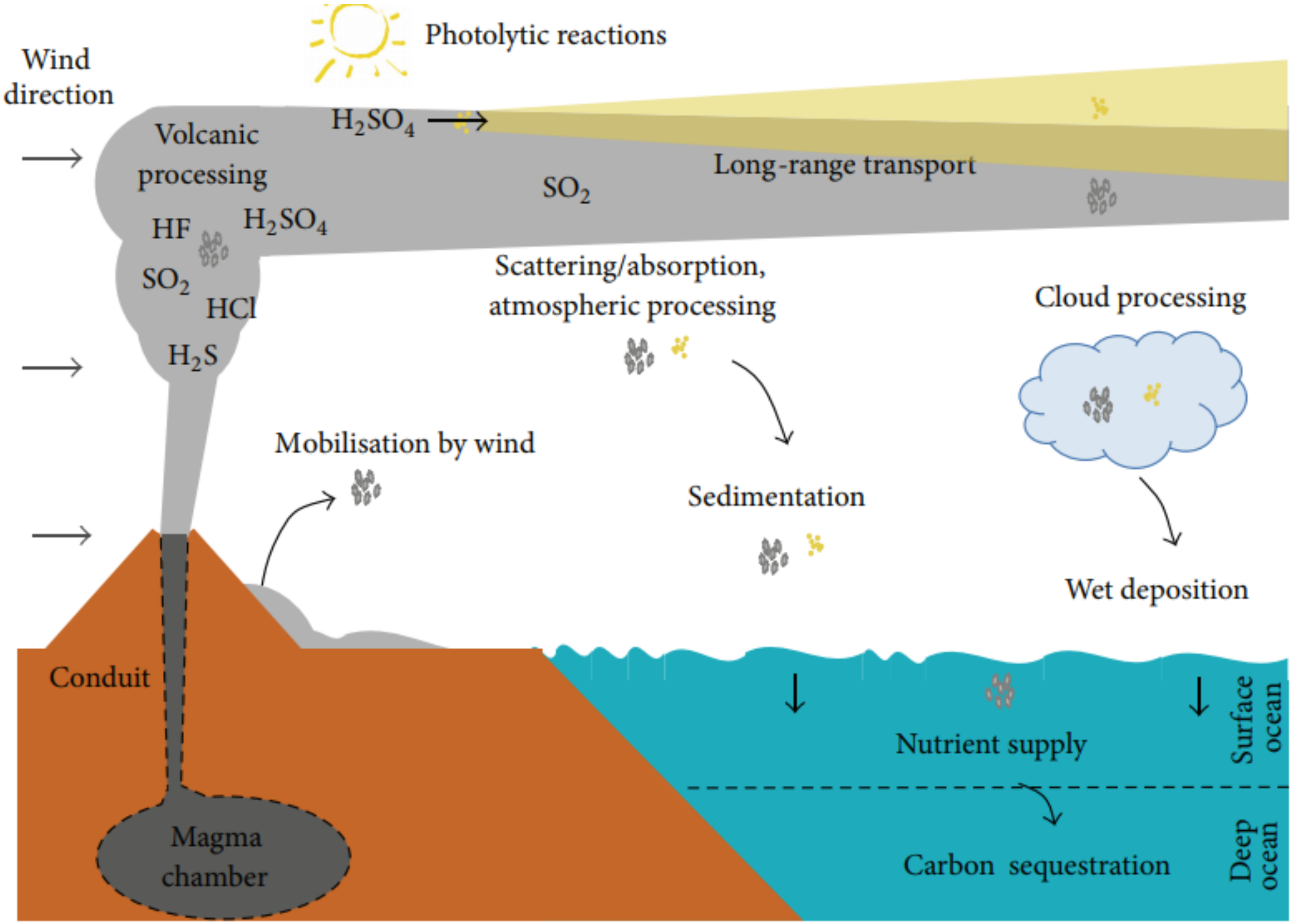
https://www.britannica.com/science/volcanism

Volcanism

- Important source of gases, aerosols and ash;
- 50-70 anual eruptions!
- Volcanic gas emissions: H_2O, CO_2, SO_2, H_2S, HCl and HF;
- **SO_2 and H_2S** - > they are oxidised and can reduce solar radiation reaching the earths's surface for years, thereby reducing surface temperatures and affecting global circulation patterns;
- Volcanic ash has a very small climatic impact: removed from the atmosphere more rapidly after an eruption – dry deposition;
- Volcanic ash may activate the "biological pump", a process that converts CO_2 to organic carbon and allows organic matter particles to sink to the deep ocean, thereby **reducing the atmospheric CO_2**.

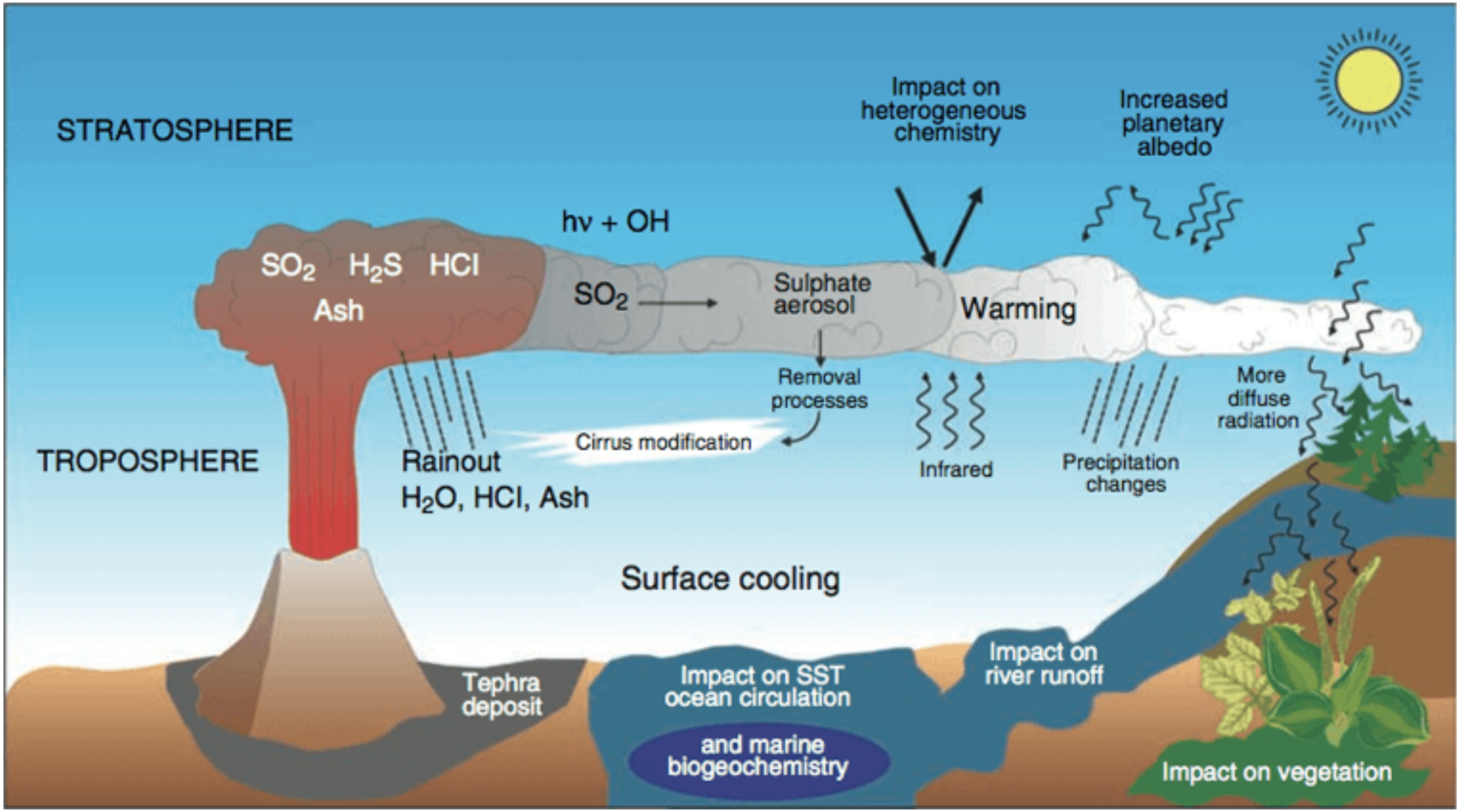
Langmann, 2014; Rampino, 1982; Robock, A., 2000

Volcanism

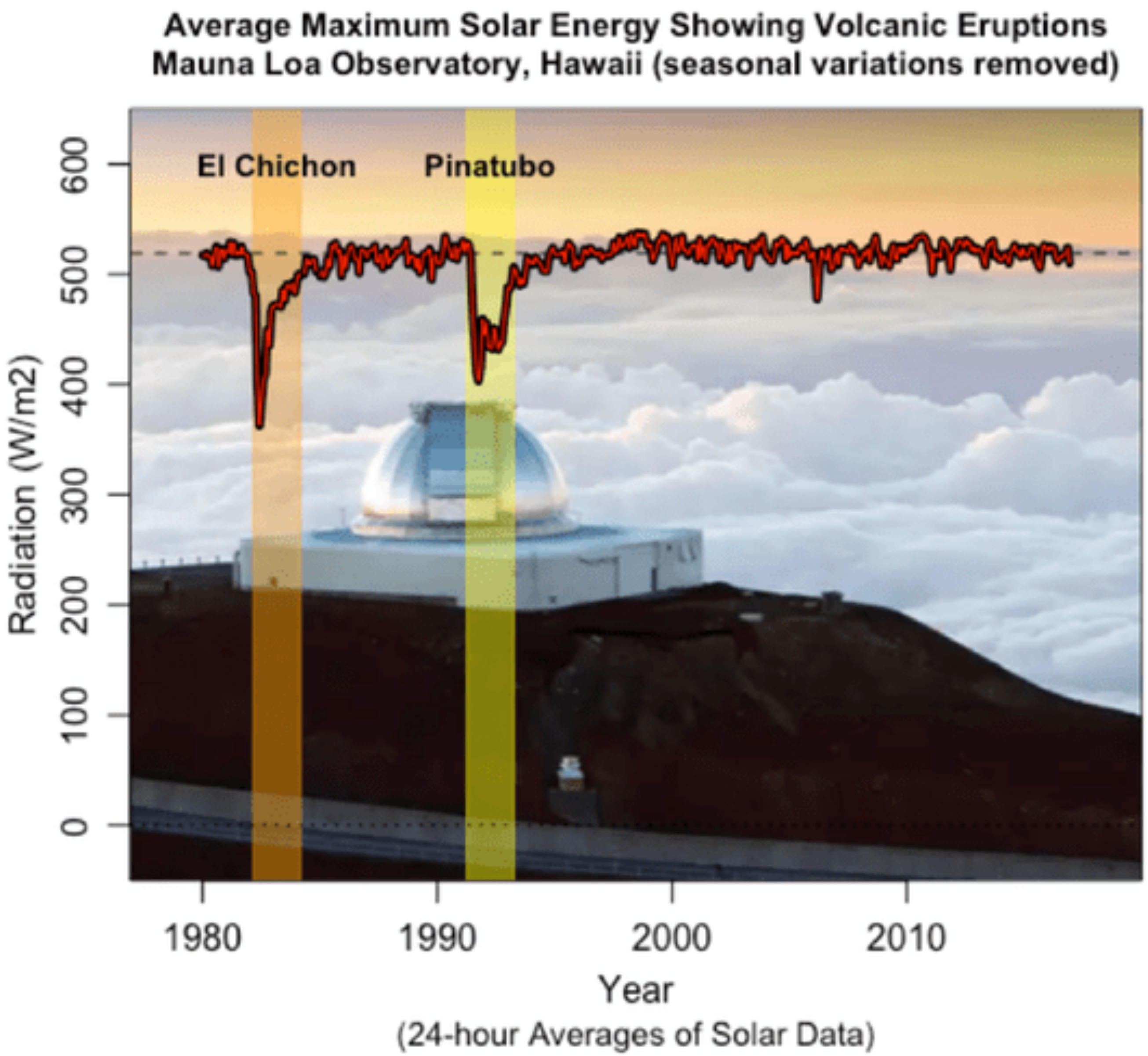


Langmann, 2014

Volcanism and Solar Irradiance

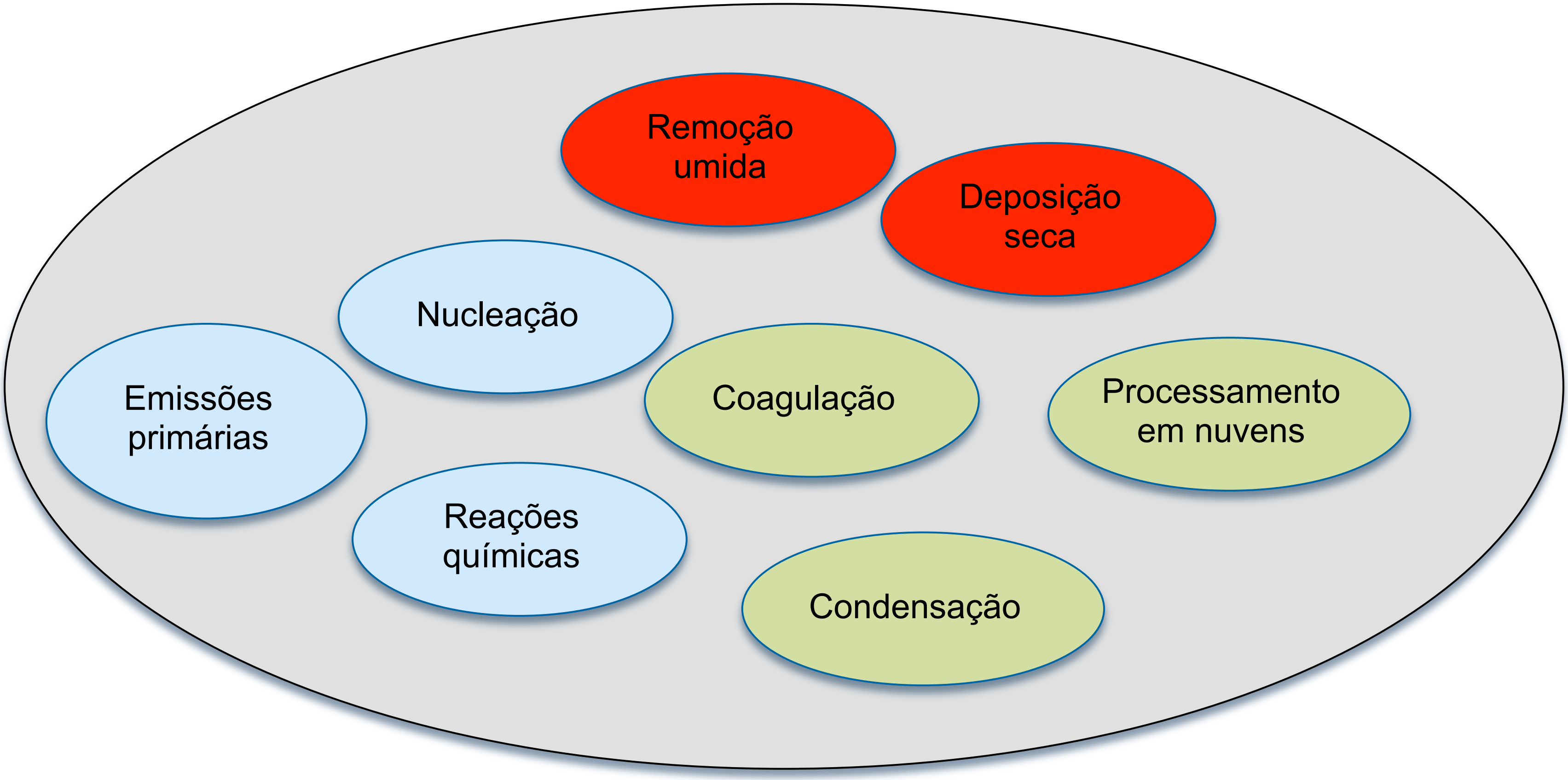


Volcanism and Solar Irradiance

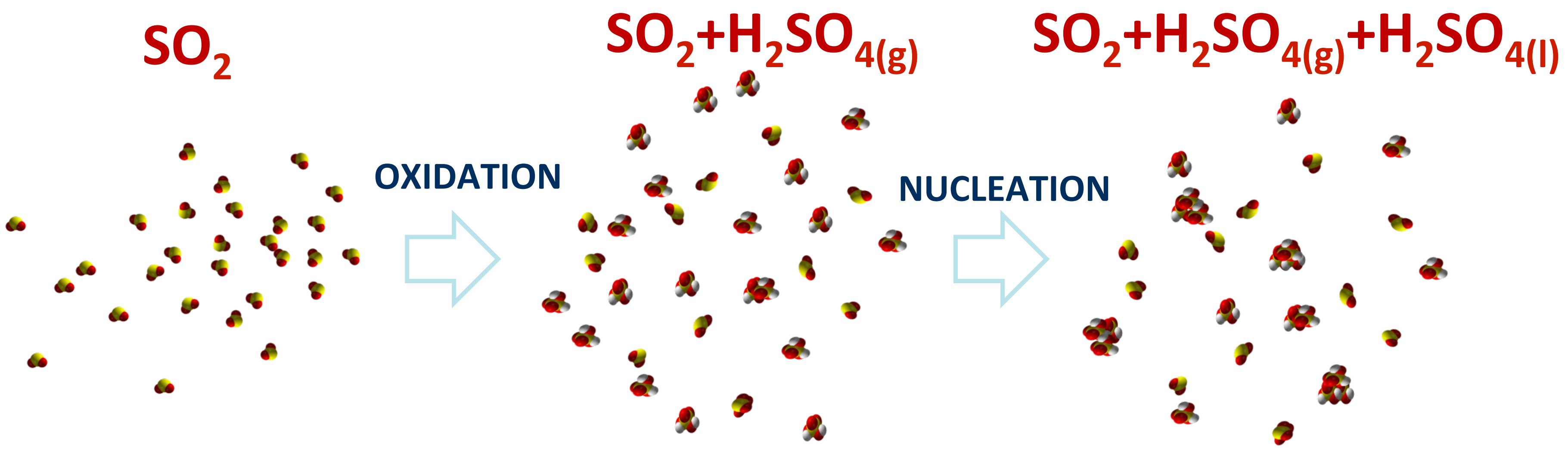


- Sea salt
- Dust
- Biomass burning
- Biogenic
- Volcanic
- Urban

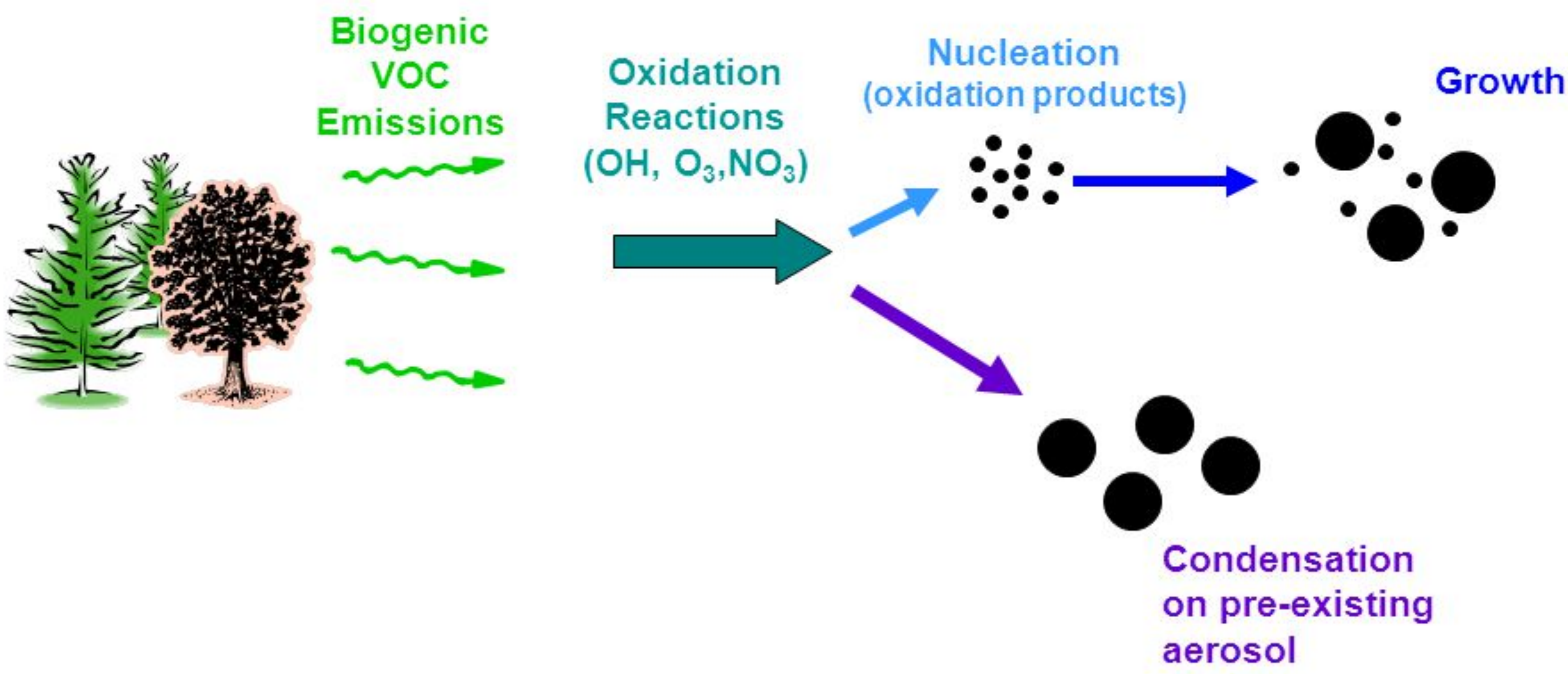
Processos envolvendo aerossóis



Nucleação



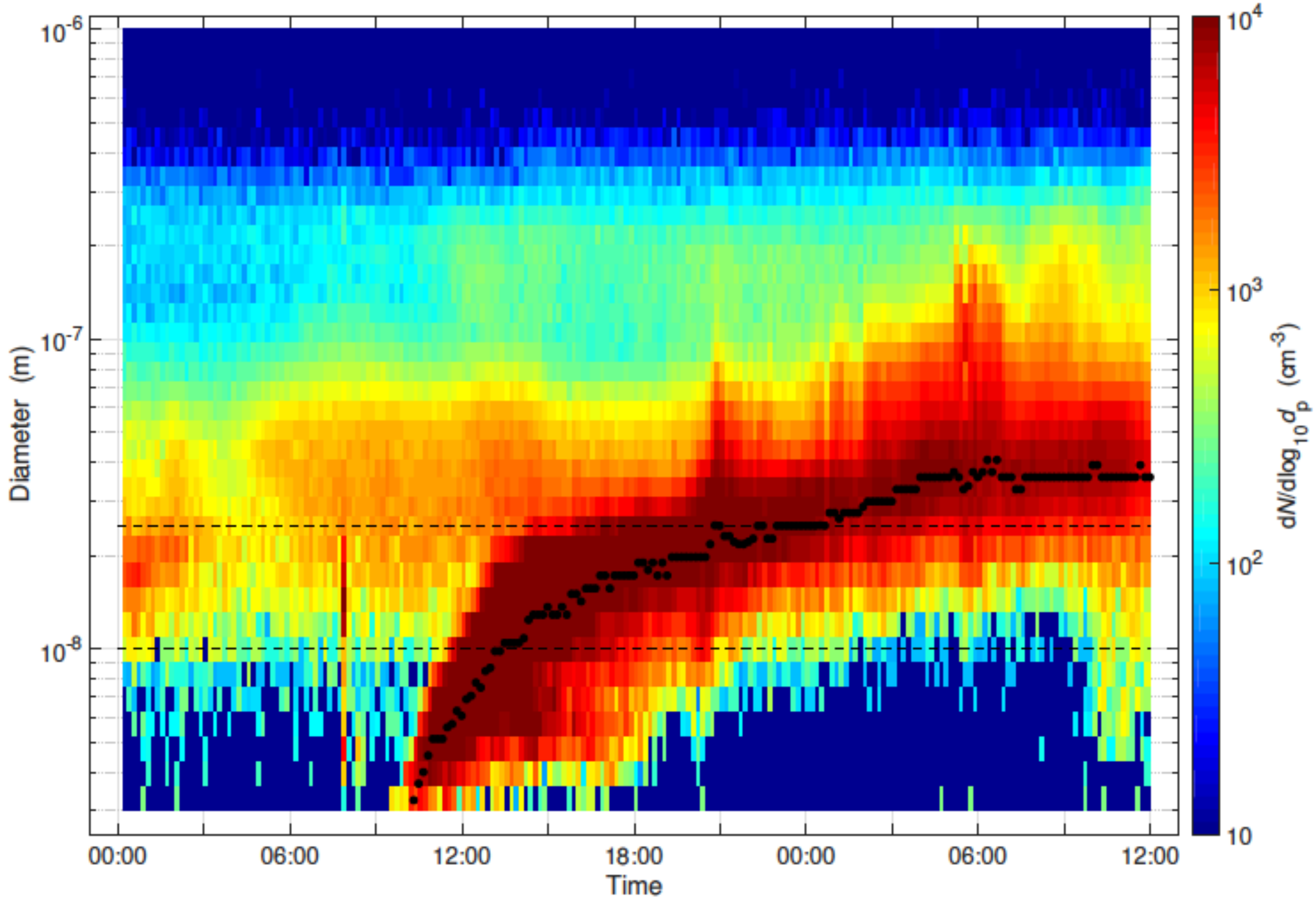
…ou Reações Químicas



Over 500 reactions to describe the formation of SOA precursors, ozone, and other photochemical pollutants [Griffin et al., 2002; Griffin et al., 2005; Chen and Griffin, 2005]

What is nucleation?

- Nucleation; A two step process
  - First step; formation of a critical nucleus during the phase transformation from vapor to liquid or solid
  - Second step; growth of the critical nucleus to a larger size (>2–3 nm) that competes with removal by preexisting aerosols
- The further growth of the particles are by condensation
- Recommendation! Read the review "New Particle Formation in the Atmosphere: From Molecular Clusters to Global Climat" by Lee et al., JGR 2018



An example of a new particle formation event observed in Hyytiälä, Finland, 15–16 March 2011, illustrating the continuous growth of the newly formed aerosol particles for about 25 h.

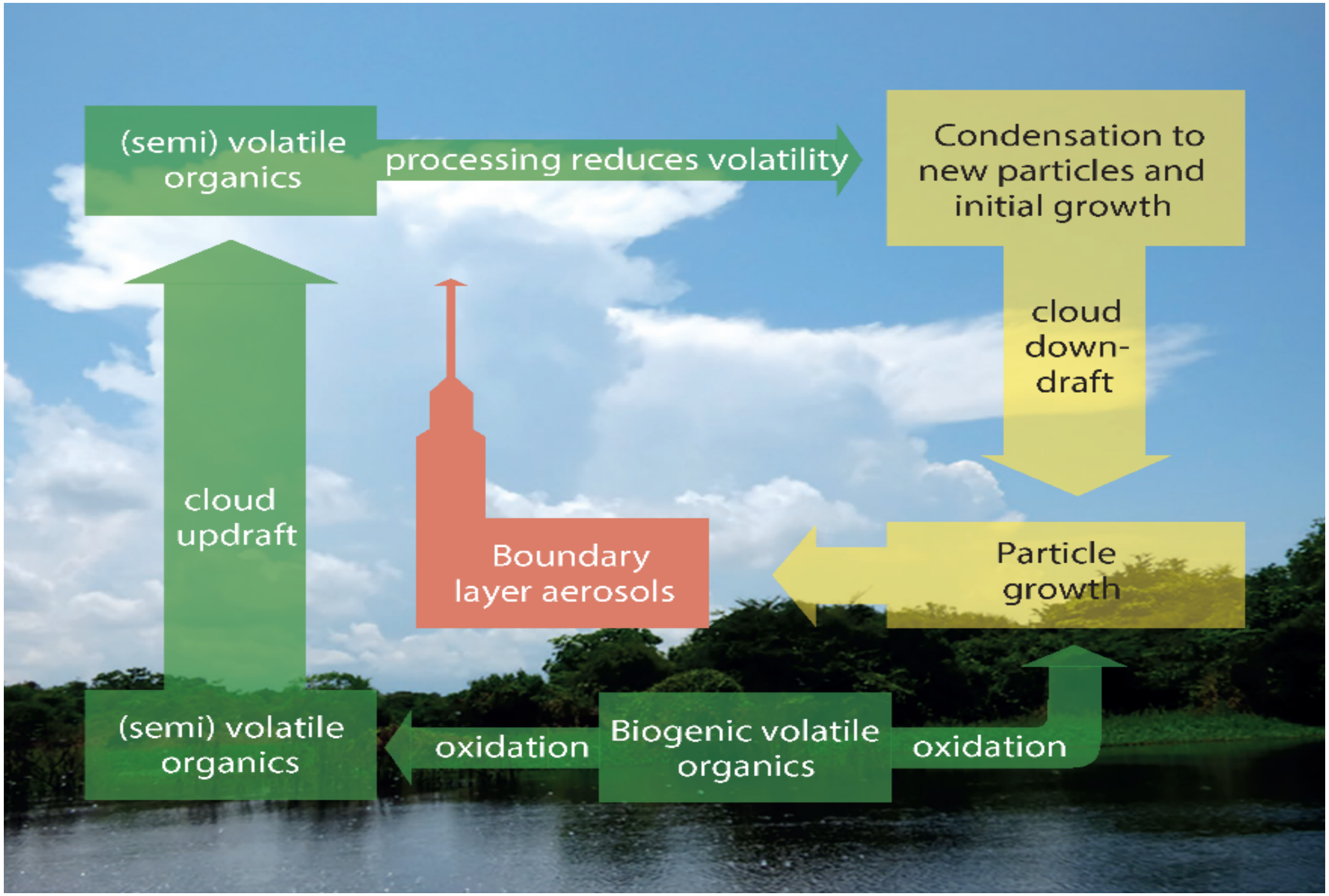
Nieminen et al, ACP, 2018

Unknowns

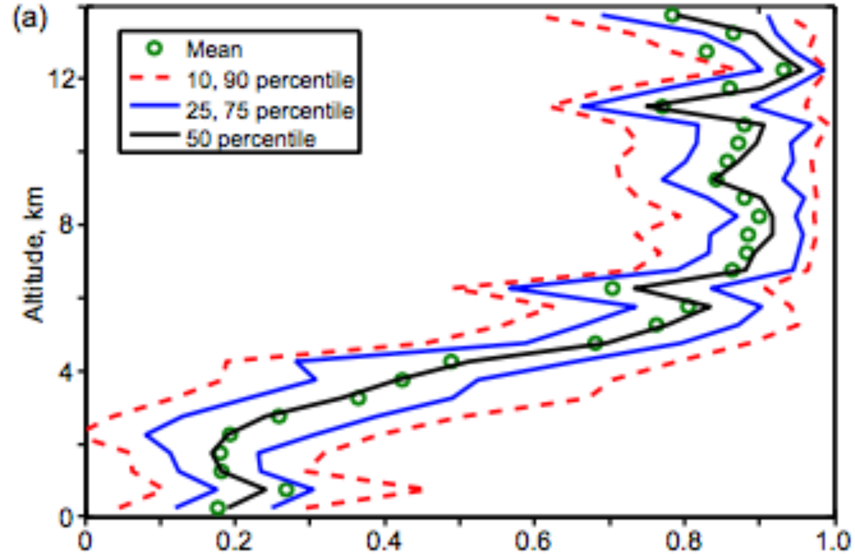
- Always H_2SO_4 but also
  - Ammonia / Amines
  - Organics
  - Ions
  - Combined give highest nucleation rates
- How is not really known
  - ”Currently, the mechanism and chemical species responsible for atmospheric NPF are still highly uncertain. In particular, consistent chemical mechanisms to explain NPF under diverse atmospheric conditions are still lacking.” (Lee et al., JGR, 2018)
- Nucleation is strongly dependent of thermodynamic parameters as RH and T
  - “Furthermore, the atmospheric conditions regulating NPF events are also poorly understood, including temperature, RH, and preexisting background aerosols.” (Lee et al., JGR, 2018)

The primary goal of CLOUD is to understand the influence of galactic cosmic rays on aerosols and clouds, and their implications for climate.

Nucleation in the Amazonas occurs in the outflow from the top of the clouds



Conceptual model of the aerosol life cycle over the Amazon Basin (from Andreae et al, 2018).



Fração ultra fina

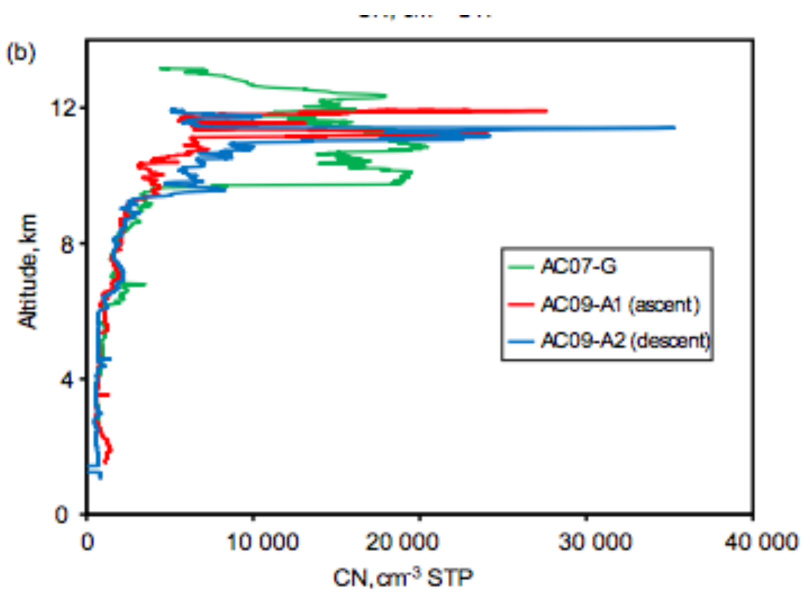


Figure 7. Vertical profiles of CN concentrations, N_{CN}; **(a)** overall statistics from all flights, **(b)** examples from individual profiles on flight AC07 (segment G) and AC09 (segments A1 and A2).