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Laboratoire Inter-universitaire des Systèmes Atmosphériques

Contribution of the laboratory experimental simulation activity within EUROCHAMP-2020/ACTRIS to the aerosol retrieval from satellite observations and modeling –

Update on lab activities, how to define experiments

Discussion: requirements for a new OPAC

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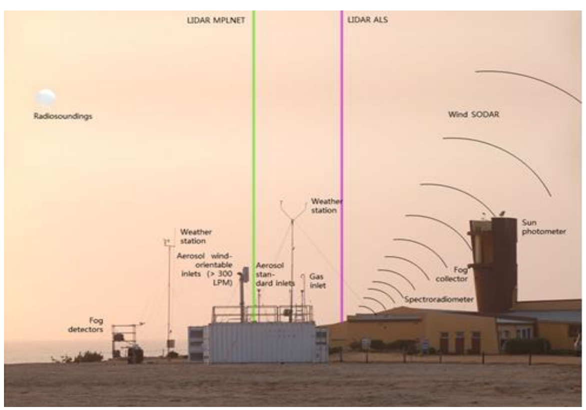
CNRS/LISA, France

AEROSAT – 16 October 2020

Why to study aerosols in simulation chambers?

To elucidate processes that occur in the atmosphere/interpret field data

To complement remote sensing observations by providing data not easily measurable in the field

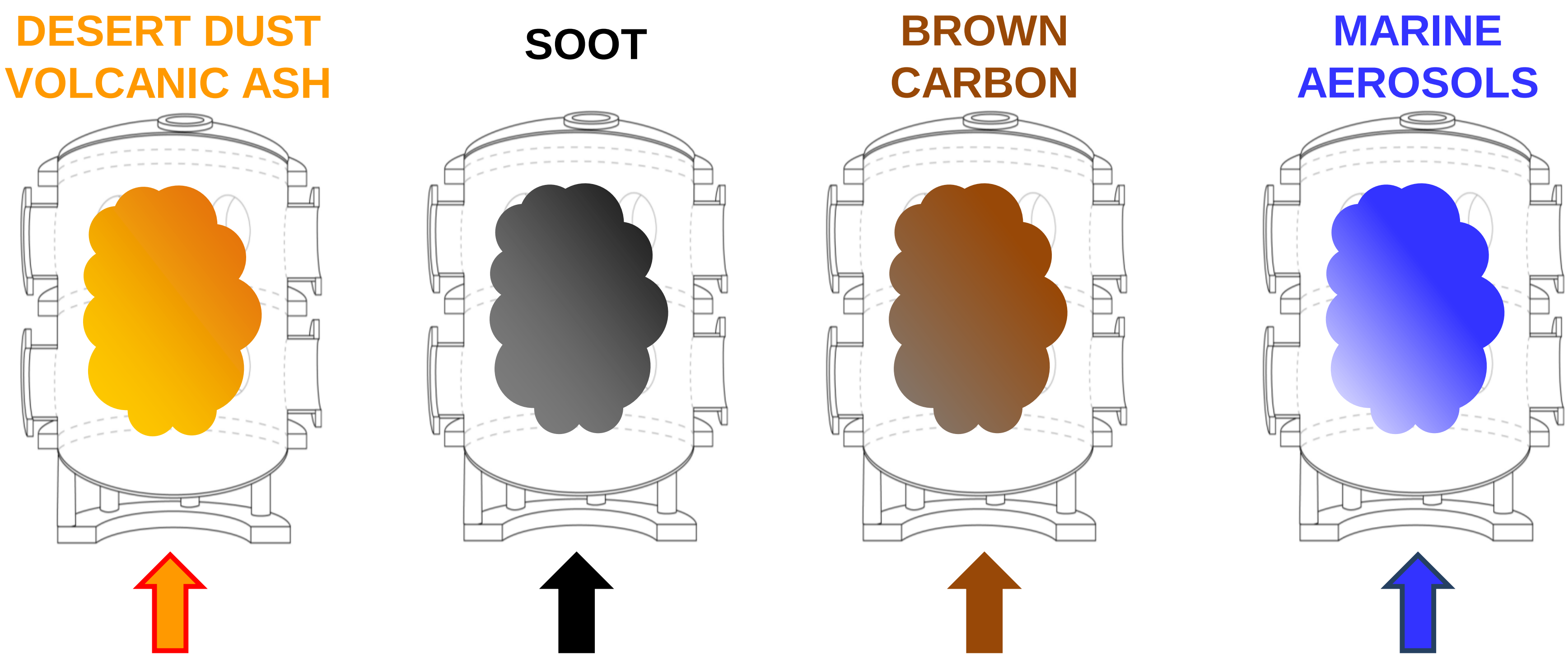


Field information

Chamber investigation

To models & remote sensing

Reproduce in the laboratory the atmospheric complexity (BUT IN A CONTROLLED WAY)



Variability of aerosol properties at the source
(modification of the aerosol generation procedure)

Simulating atmospheric aging
(multiphasic reactions, aerosol mixing, photochemistry, etc.)

What we can do, what we can measure, what we can get

INPUT
Aerosols
(primary/secondary)
Gases
Water vapor
Clouds
Irradiance

Measurements aerosols

Size distribution

Mass concentration

Composition (bulk & size-dependent)

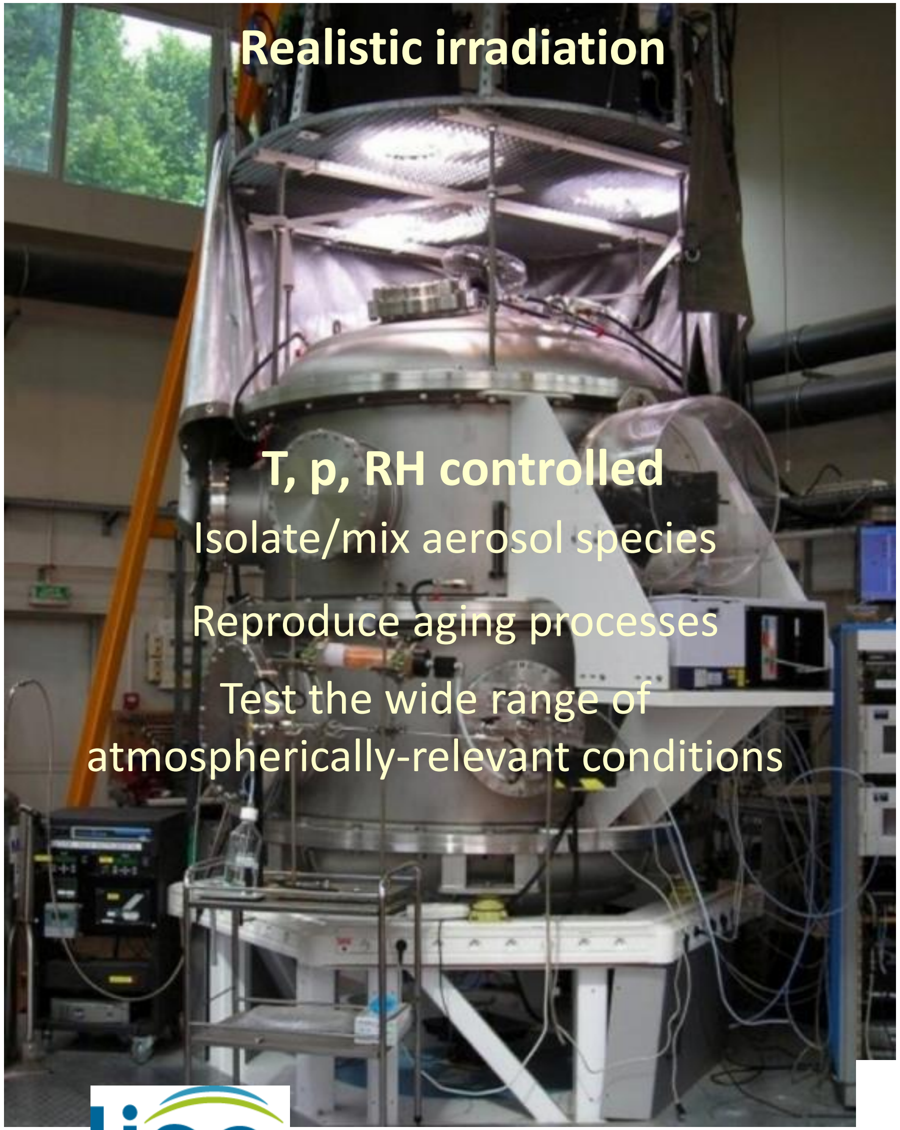
Morphology

Ext/abs/sca coefficients ex situ (discrete λ)

High resolution (<1 nm) SW/LW extinction in situ

Growth Factor, CCN

CESAM chamber, 4.2 m^3 stainless steel



Retrieved intensive spectral optical propeties (dry & wet)

Mass ext/abs/sca efficiencies (MEE/MAE/MSE)

Complex refractive index (CRI)
Shape dependent inversion combining size/optical data

Single Scattering Albedo (SSA)

Phase function
Shape dependent optical calculations

Hygroscopicity

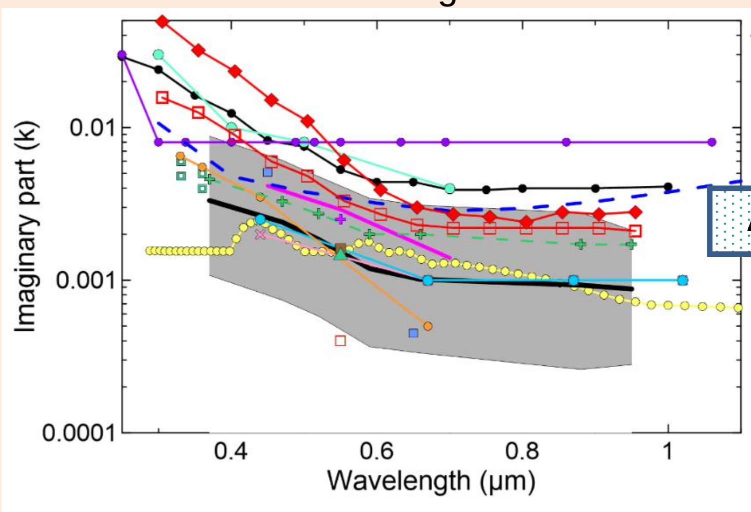
www.cesam.cnrs.fr

Ongoing projects in CESAM: mineral dust

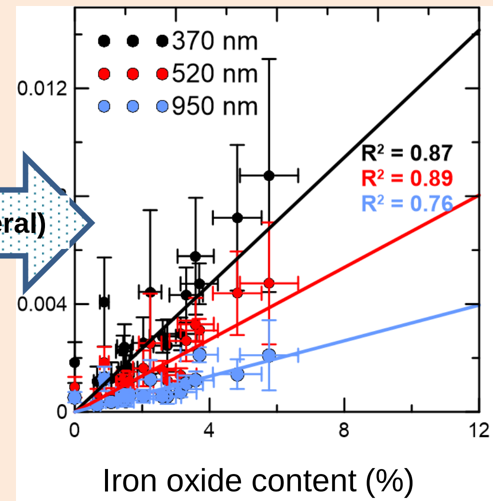
Objective: SW and LW CRI/MEE/SSA for dry « pure » dust aerosols from desert sources representative of global extremes in mineralogy. Link to particle mineralogy & size

SW and LW CRI range vs literature

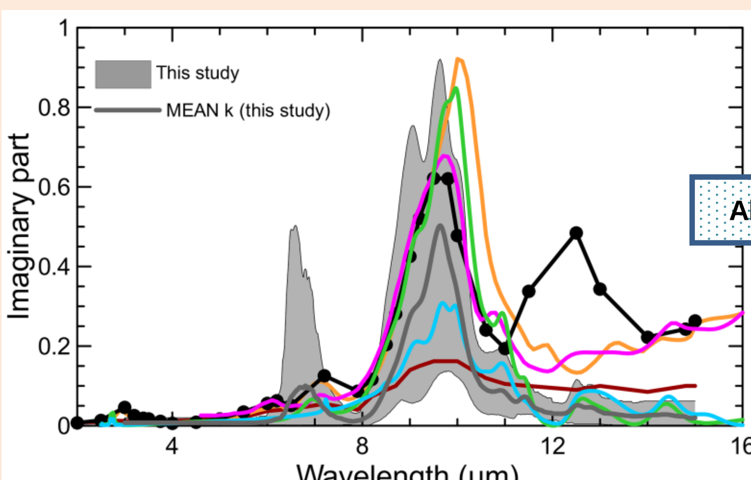
Di Biagio et al. GRL 2104, ACP 2017, 2019; Caponi et al., 2017



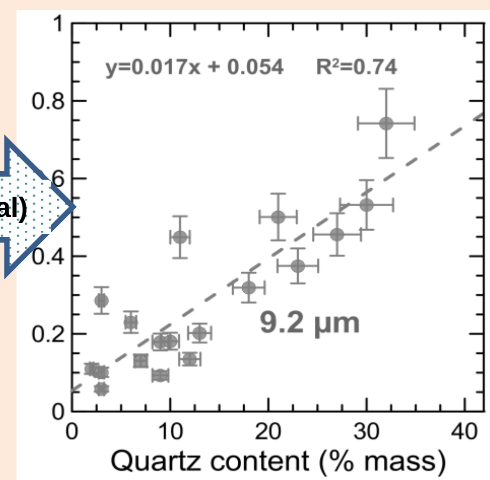
Absorption (λ) = f (minéral)



SW



Absorption (λ) = f (minéral)



LW

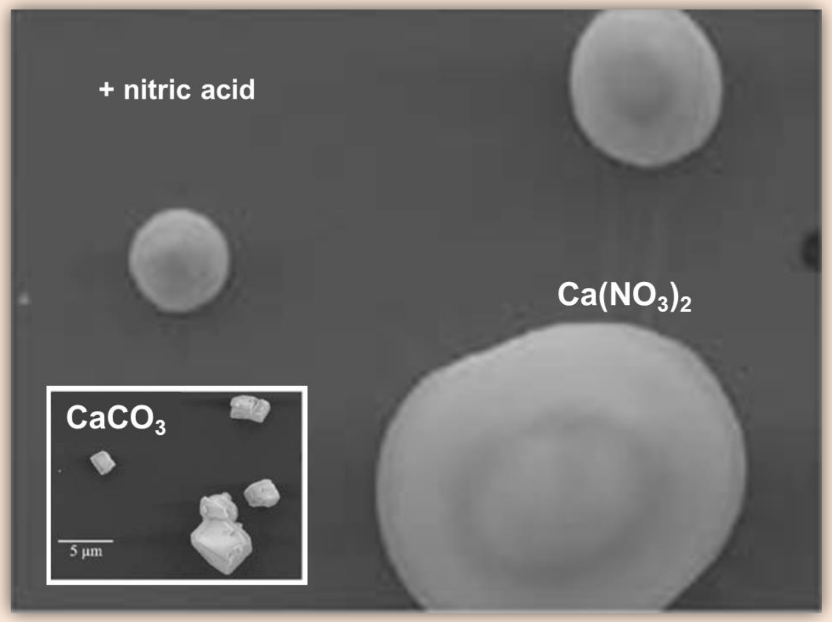
Funded projects: **REDDUST** (2015-2016) ***TNA activities***: *prof J. King*, *A. Chaput*, Univ Montreal

Ongoing projects in CESAM: mineral dust

Objective: to investigate the ageing of mineral dust by the heterogeneous reactions with organic species (as limonene, glyoxal, methylglyoxal) and the impact on SW/LW optical properties (CRI, MEE/MAE/MSE) and hygroscopicity

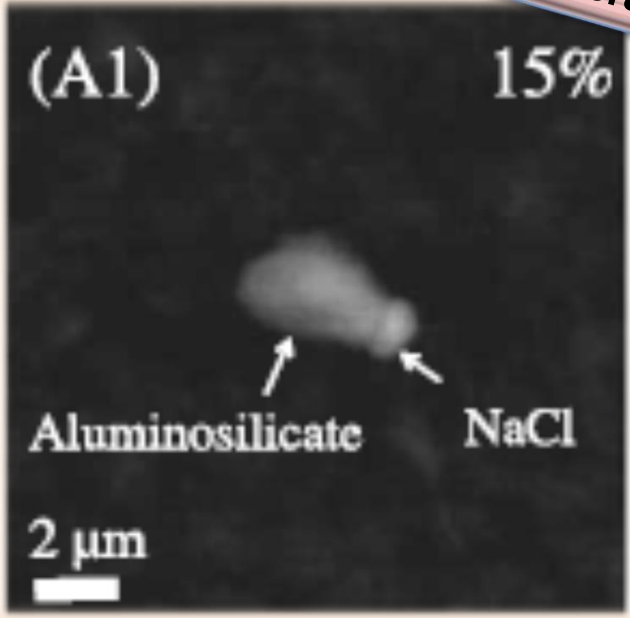
Chemical aging depends on mineralogy and RH

Heterogeneous chemistry at the particle surface



adapted from Laskin et al. (2005)

Particle mixing

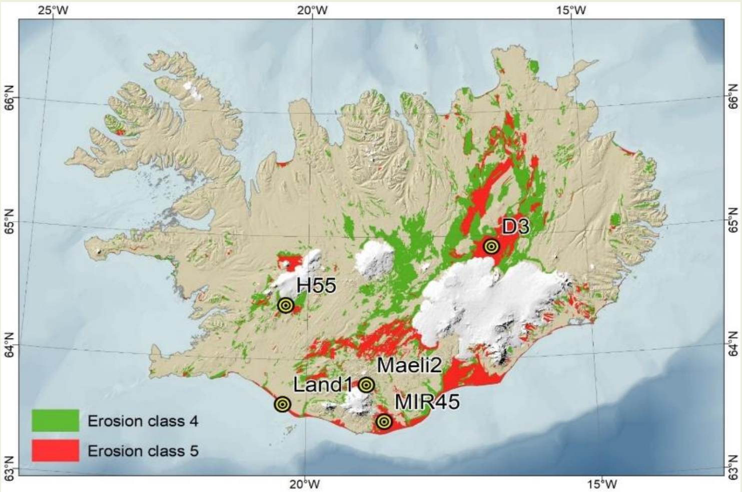


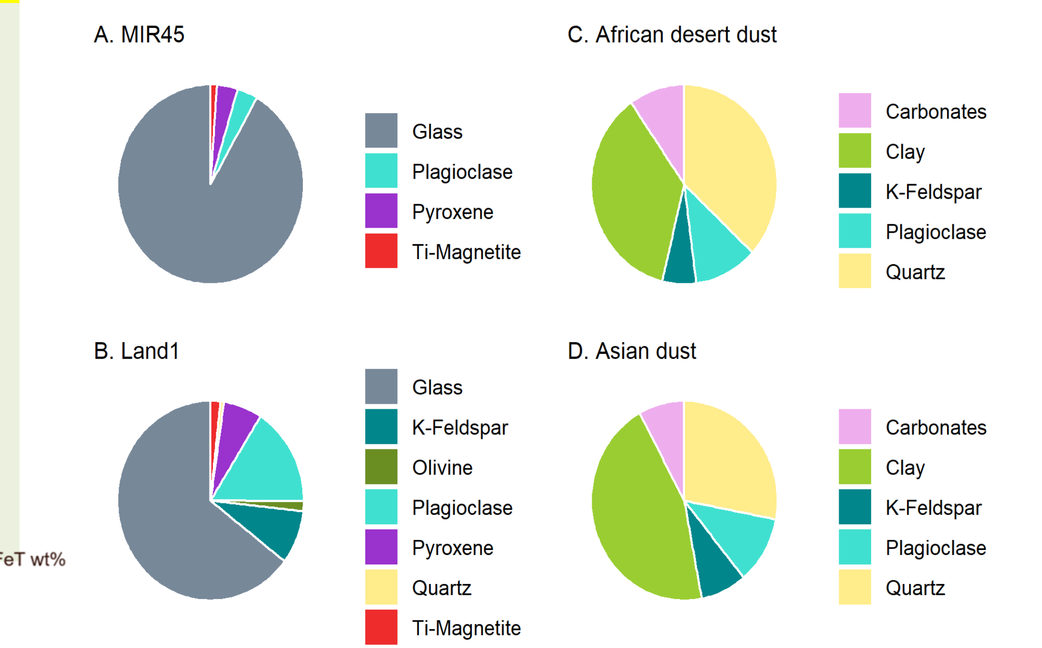
adapted from Denjean et al. (2015)

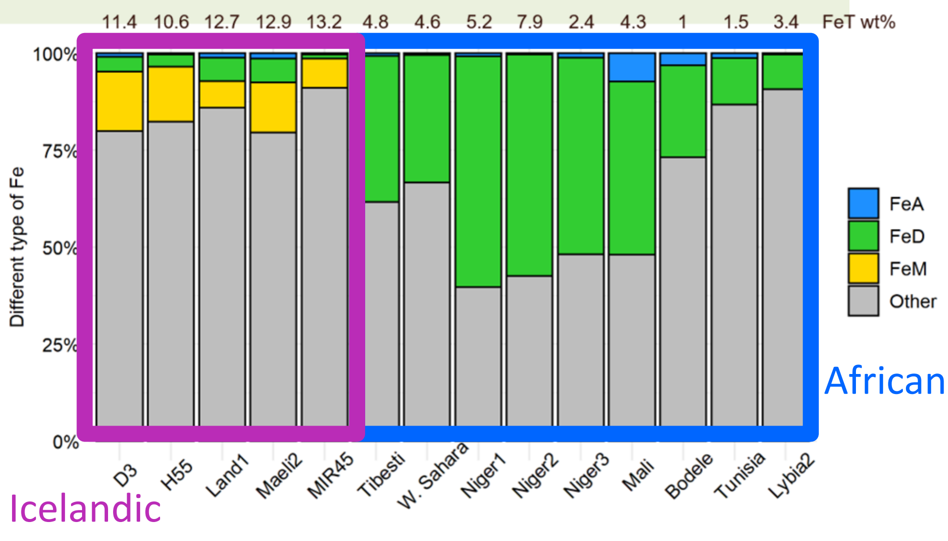
Funded projects: **INVOC-DUST** (2018-2020), **CLIMDO** (2020-2024), *PI P. Formenti*

Ongoing projects in CESAM: volcanic ashes

Objective: SW and LW (CRI/MEE/SSA) for « pure » dry ashes from different Icelandic sources with different mineralogy. Link to particle mineralogy and size







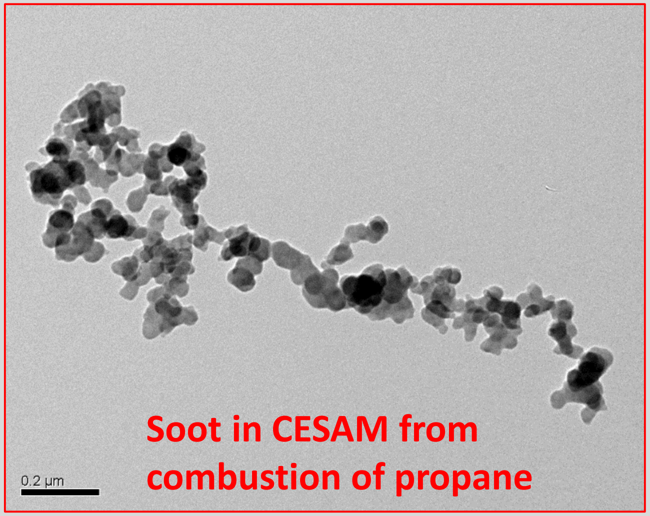
Different mineralogy and iron oxide speciation than mineral dust *(Baldo et al. ACP 2019)*

Investigating SW and LW optical properties for volcanic ashes *(Baldo et al. in preparation)*

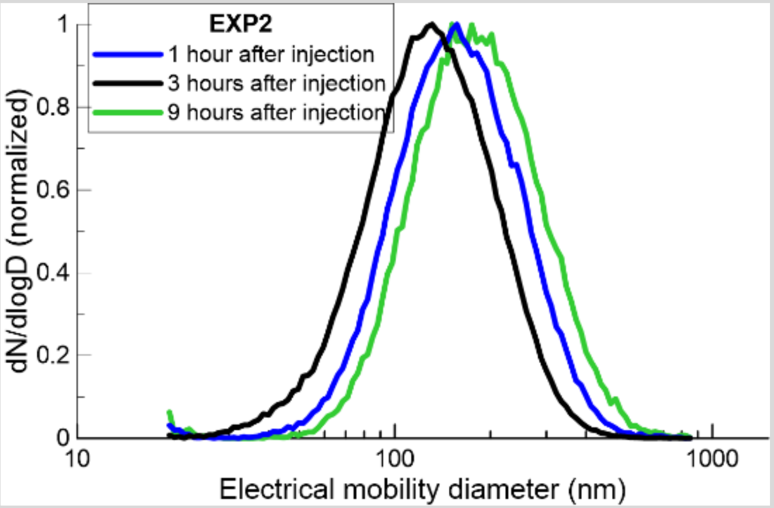
TNA activities: *prof Z. Shi, C. Baldo*, Univ Birmingham, UK

Ongoing projects in CESAM: <u>black and brown carbon</u>

Objective: SW and LW (CRI/MEE/SSA) for « pure » and « aged » primary and secondary BC and BrC aerosols issued from different combustion processes and chemical reactions. Link to particle composition, morphology and size



Use of optical theories adapted for fractal aggregates (e.g., RDG-FA, Rayleigh–Debye–Gans theory for Fractal–Aggregates) in modeling optical signals for retrieving the spectral CRI



Evolution of size distribution for 9-hours aging, SSA(550 nm) unchanged ~0.35

Funded project: **BACON** (2019-2021), **B2C** (2020-2024), *PI C. Di Biagio*

TNA activities: *prof D. De Haan*, Univ San Diego, California

How to define laboratory chamber experiments?

Target species: investigate *realistic* samples covering the range of global- and regional-relevant variability (composition, size)

size possibles in lab experiments (type-dependent) : tenths of nm to tenths of µm

Target variables: intensive optical properties (ex., CRI)

Transfer to models/inversion algorithms: having as much as possible clear how this can be done (ex. which parameters are traced in models, assumptions,,..)

→ *exchange information (ex. this session)*

Get the accuracy required by models / retrieval algorithms

Requirements for a new OPAC

Revise/test the CRI dataset
(retrieved for airborne/suspended aerosol samples or other, dry and ambient RH; regional-variability, fresh-aged aerosols, mixing)

Provide higher spectral resolution data

CRI/MEE/SSA/phase function for non-spherical particles (ex. fractal aggregates)

……

OPAC (Hess et al., 1998)), OPAC 4.0 (Koepke et al., 2015)

10 aerosol components (lognormal size distribution, CRI (0.25-40 µm, 61 λ)
8 RH = 0, 50,70, 80, 80, 95, 98, 99%

Component	File name	σ	r'_{modN} (µm)	r'_{modV} (µm)	r'_{min} (µm)	r'_{max} (µm)	
Insoluble	INSO	2.51	0.471	6.00	0.005	20.0	soil+organic
Water-soluble	WASO	2.24	0.0212	0.15	0.005	20.0	sulfates+nitrates+organic
Soot	SOOT	2.00	0.0118	0.05	0.005	20.0	
Sea salt (acc. mode)	SSAM	2.03	0.209	0.94	0.005	20.0	
Sea salt (coa. mode)	SSCM	2.03	1.75	7.90	0.005	60.0	
Mineral (nuc. mode)	MINM	1.95	0.07	0.27	0.005	20.0	
Mineral (acc. mode)	MIAM	2.00	0.39	1.60	0.005	20.0	
Mineral (coa. mode)	MICM	2.15	1.90	11.00	0.005	60.0	
Mineral-transported	MITR	2.20	0.50	3.00	0.02	5.0	
Sulfate droplets	SUSO	2.03	0.0695	0.31	0.005	20.0	Antarctic/ stratospheric aerosols

Increasing RH:
- the radius increases and the CRI is recalculated as a mixing of component and water CRI

OPAC (Hess et al., 1998), OPAC 4.0 (Koepke et al., 2015)

13 aerosol types (mixing of components)

free to mix components as preferred to create your own aerosol type

Mie theory (updated to spheroidal calculations in OPAC 4.0 for mineral dust only)

Aerosol types	Components	N_i (cm^{-3})	M_i ($\mu g\ m^{-3}$)
Continental clean	total	2600	8.8
	water soluble	2600	5.2
	insoluble	0.15	3.6
Continental average	total	15 300	24.0
	water soluble	7000	14.0
	insoluble	0.4	9.5
	soot	8300	0.5
Continental polluted	total	50 000	47.7
	water soluble	15 700	31.4
	insoluble	0.6	14.2
	soot	34 300	2.1
Urban	total	158 000	99.4
	water soluble	28 000	56.0
	insoluble	1.5	35.6
	soot	130 000	7.8
Desert	total	2300	225.8
	water soluble	2000	4.0
	mineral (nuc.)	269.5	7.5
	mineral (acc.)	30.5	168.7
	mineral (coa.)	0.142	45.6
Maritime clean	total	1520	42.5
	water soluble	1500	3.0
	sea salt (acc.)	20	38.6
	sea salt (coa.)	3.2E–3	0.9
Maritime polluted	total	9000	47.4
	water soluble	3800	7.6
	sea salt (acc.)	20	38.6
	sea salt (coa.)	3.2E–3	0.9
	soot	5180	0.3
Maritime tropical	total	600	20.8
	water soluble	590	1.2
	sea salt (acc.)	10	19.3
	sea salt (coa.)	1.3E–3	0.3
Arctic	total	6600	6.8
	water soluble	1300	2.6
	insoluble	0.01	0.2
	sea salt (acc.)	1.9	3.7
	soot	5300	0.3
Antarctic	total	43	2.2
	sulfate	42.9	2.0
	sea salt (acc.)	0.47E–1	0.1
	mineral (tra.)	0.53E–2	0.1

OPAC (Hess et al., 1998), OPAC 4.0 (Koepke et al., 2015)

13 aerosol types (mixing of components)

free to mix components as preferred to create your own aerosol type

Mie theory (updated to spheroidal calculations in OPAC 4.0 for mineral dust only)

Aerosol type	σ_e (0.55 μm) (km^{-1})	σ_e^* (0.55 μm) ($m^2\ g^{-1}$)	τ (0.55 μm)	Vis (km)	ω_o (0.55 μm)	g (0.55 μm)	α (0.35–0.5)	α (0.5–0.8)
Continental clean	0.026	2.39	0.064	79	0.972	0.709	1.10	1.42
Continental average	0.075	2.51	0.151	35	0.925	0.703	1.11	1.42
Continental polluted	0.175	2.86	0.327	16	0.892	0.698	1.13	1.45
Urban	0.353	2.87	0.643	8	0.817	0.689	1.14	1.43
Desert	0.145	0.64	0.286	19	0.888	0.729	0.20	0.17
Maritime clean	0.090	1.29	0.096	30	0.997	0.772	0.12	0.08
Maritime polluted	0.115	1.50	0.117	24	0.975	0.756	0.41	0.35
Maritime tropical	0.043	1.26	0.056	55	0.998	0.774	0.07	0.04
Arctic	0.023	2.17	0.063	88	0.887	0.721	0.85	0.89
Antarctic	0.011	3.33	0.072	130	1.000	0.784	0.34	0.73
Mineral transported (2–3.5 km)	0.064	0.37	0.097	—	0.837	0.775	−0.10	−0.13
Free troposphere (2–12 km)	—	—	0.013	—	0.934	—	1.21	1.58
Stratosphere (12–35 km)	—	—	0.005	—	1.000	—	0.74	1.14

Hess et al., 1998