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Rapid transformation of ambient absorbing aerosols from West African biomass burning during MOYA-2017

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Met Office

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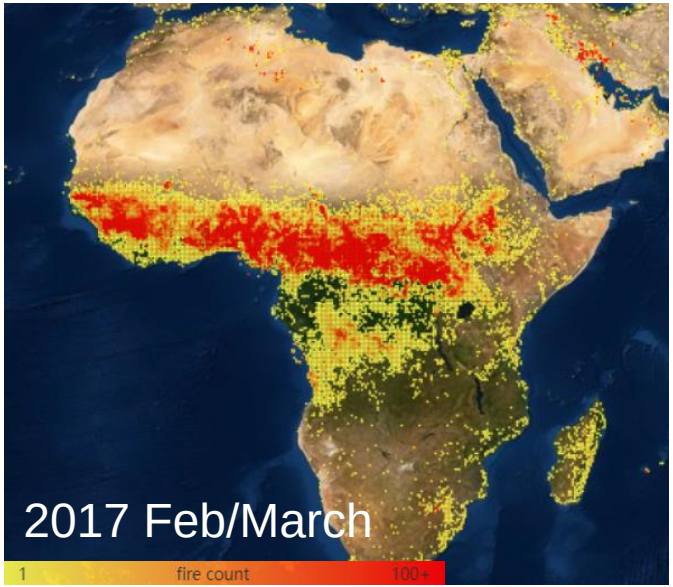
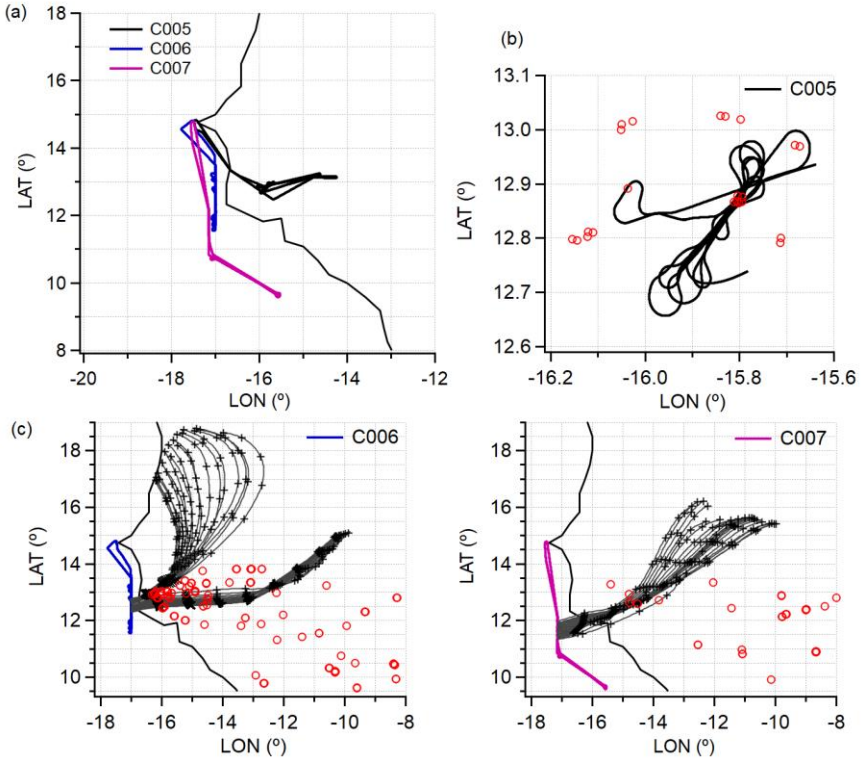
MOYA-2017 overview



- MOYA-2017 aircraft campaign focused on the seasonal biomass burning (BB) over West Africa, which is a globally significant source of carbonaceous particles in the atmosphere but has been poorly constrained.
- MOYA investigated the gas and aerosol emissions, and their evolution
- This study focuses on the aging process of submicron BB aerosols emitted from flaming burning of savanna.

Plume classification & age identification



< 0.5 h	Directly over fires
~ 1–2 h	Downwind air over continent
~ 3–6 h	Transported over Atlantic
~ 9–12 h	Transported over Atlantic

Note: The plume age over Atlantic was estimated using UK Met Office NAME back trajectory.

	< 0.5 h	**~ 1–2 h**	**~ 3–6 h**	**~ 9–12 h**
Date	01/03	01/03	01/03	02/03
Aircraft Altitude (m)	380 – 1474	397 – 1485	1651 – 1728	1482 – 1796
Temperature (°C)	29.3 ± 3	27.4 ± 3	23.1 ± 0.3	22.4 ± 0.5
RH (%)	16 ± 2	17 ± 2	19 ± 1	25 ± 3
MCE ***(flaming controlled)***	0.94 – 0.96	0.94 ± 0.01	0.94 ± 0.01	0.95 ± 0.01

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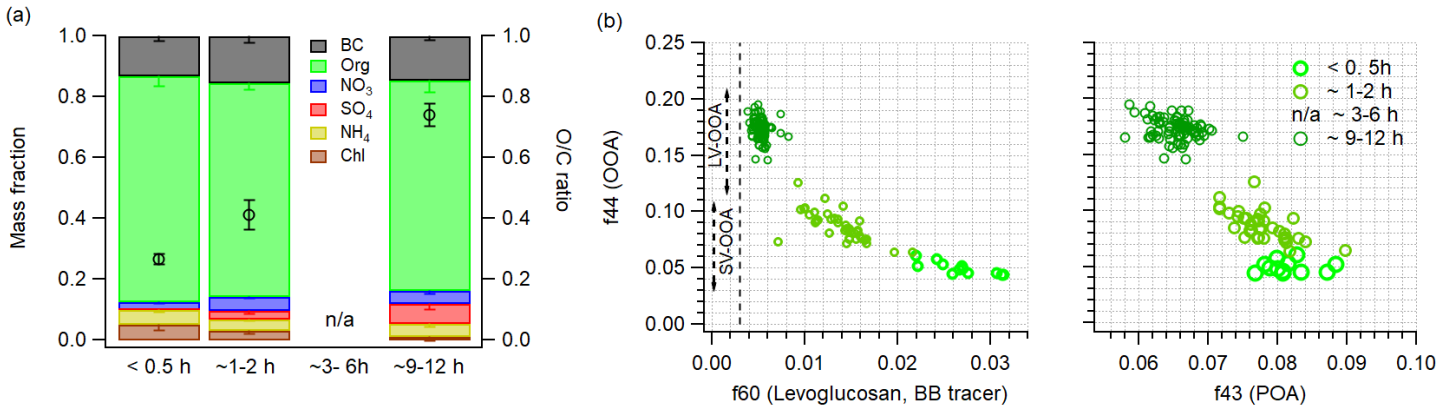
Analysed aerosol data

For dry submicron aerosol

Chemical composition	AMS (C006 data lost)	1. Aerosol mass concentrations of organics, NO_3, SO_4, NH_4 , Chloride 2. Organic composition, oxidation state	University of Manchester
	SP2	BC mass and number concentration	University of Manchester
Size	SP2	BC core size and shell/core ratios (coating state)	University of Manchester
	SMPS	Bulk aerosol size distributions (20 – 350 nm)	University of Manchester
Optical: SSA, AAE MAC of OA and BC	PAS	dry aerosol absorption coefficient	UK Met Office
	CRD	dry aerosol extinction coefficient	UK Met Office

Chemical evolution



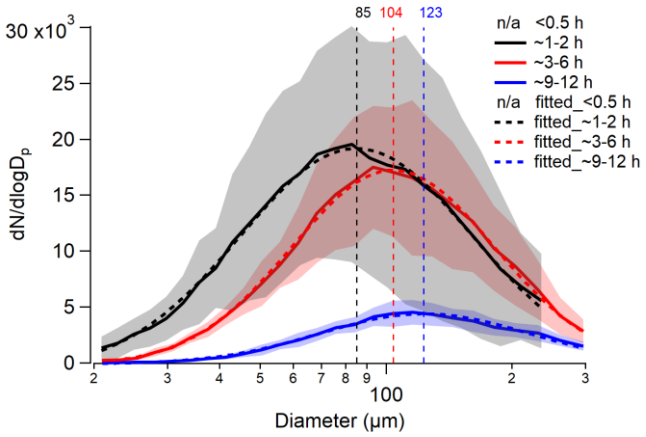
- The enhanced inorganic (nitrate and sulphate) fraction of aerosols
- The decay of levoglucosan-like species and other related primary OA
- More oxidized OA state and lower volatility with aging

	< 0.5 h	~ 1–2 h	~ 3–6 h	~ 9–12 h
OM/OC	1.52 ± 0.03	1.70 ± 0.06	-	2.11 ± 0.05
ΔOA/ΔBC	7.0 ± 0.9	5.5 ± 0.5	-	5.6 ± 0.3
ΔOC/ΔBC	4.7 ± 0.5	3.5 ± 0.3	-	2.7 ±0.1

- The evaporation losses of organic carbon dominated over the addition of organic carbon from secondary material in these plumes
- OA mass initially decreased due to the evaporation loss, followed by little change in later aging process

Size evolution

Bulk aerosol size distributions



BC core size and coatings

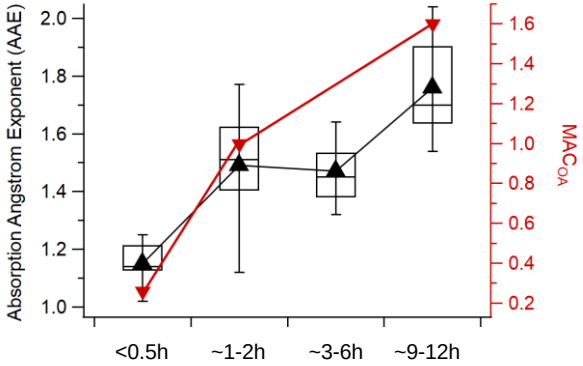
		< 0.5 h	~ 1–2 h	~ 3–6 h	~ 9–12 h
BC core size, MMD		196 ± 9	192 ± 8	191 ± 5	192 ± 12
BC core size, CMD		109 ± 5	104 ± 3	106 ± 2	107 ± 3
BC shell/core ratios	10%	1.03	1.28	1.40	1.70
	Median	1.15	1.42	1.49	1.75
	90 %	1.25	1.57	1.56	1.82
	Avg ± Std	1.14 ± 0.10	1.43 ± 0.10	1.48 ± 0.07	1.75 ± 0.04

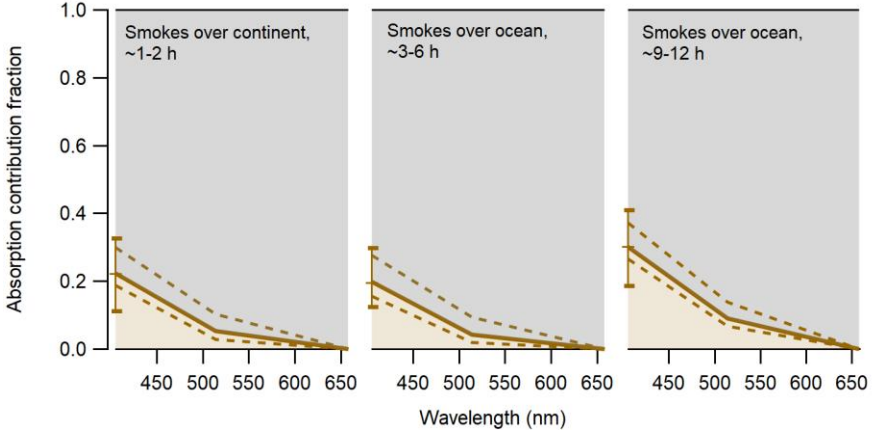
- We mainly detected single dominant accumulation mode of bulk aerosols at different ages.
- The enhanced bulk aerosol CMD due to the coagulation and condensation processes after emission.

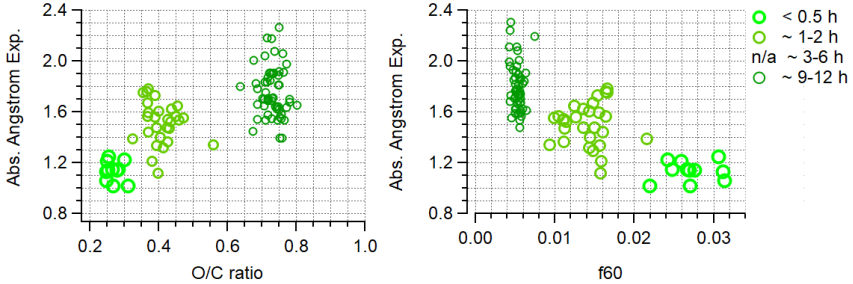
- The effects of BC–BC coagulation are likely to be minor after emission.
- BC was dominantly externally mixed with other co-emitted particles when emission (<0.5 h), and gradually became internally mixed with other species.

Optical evolution

1. AAE and implications of BrC:







- AAE is often used to indicate the presence of non-BC absorbing particles, when AAE is over 1 (Lack and Langridge, 2013).
- BrC was likely a minor component in source emission but was formed during half-day transport, and had increasing importance on absorption.
- BrC in this study is poorly related to the primary OA, but closely related to some oxygenated and low-volatile OA formed with aging process.

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Optical evolution

2. Absorption enhancement ($E_{Abs\text{-}MAC}$)

	~ 1–2 h	~ 3–6 h	~ 9–12 h
$E_{abs\ (405)}$	1.34	1.44	1.77
$E_{abs\ (514)}$	1.15	1.23	1.66
$E_{abs\ (658)}$	1.17	1.29	1.75

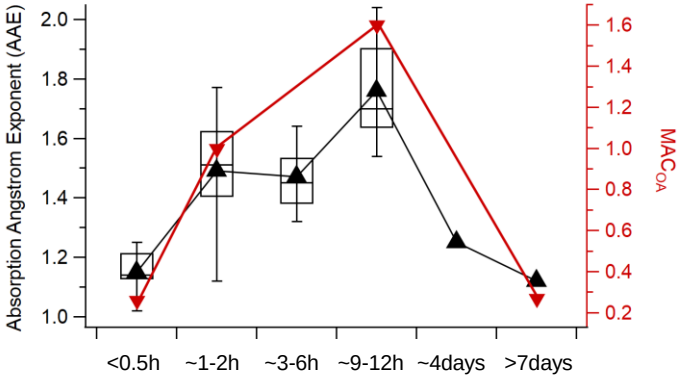
- $E_{Abs\text{-}MAC}$ represents the additional absorption of sunlight except BC cores, that is due to the lensing effect of coatings on BC cores and the absorption by BrC.
- Enhanced $E_{Abs\text{-}MAC}$ with aging

3. Single scattering albedo (SSA)

		~ 1–2 h	~ 3–6 h	~ 9–12 h
SSA_{658}	10%	0.80	0.83	0.88
	Median	0.84	0.85	0.89
	90%	0.88	0.86	0.90
	Avg ± Std	0.83 ± 0.07	0.85 ± 0.01	0.89 ± 0.01
SSA_{405}	10%	0.83	0.86	0.92
	Median	0.88	0.87	0.94
	90%	0.93	0.91	0.95
	Avg ± Std	0.88 ± 0.05	0.88 ± 0.02	0.94 ± 0.01

- Mass scattering coefficient (MSC_{PM_1}) at 405 nm increased from (18.5 $\pm$ 5.5) to (29.7 $\pm$ 4.3) after half-day aging.
- The increasing SSA was consistent with the enhanced scattering, likely due to the growing particle size

Optical evolution

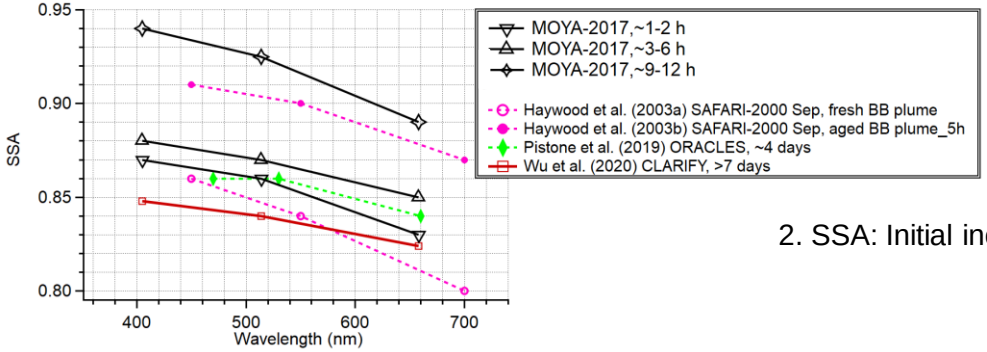


- Combining results from *ORACLES* and *CLARIFY* campaigns, which also measured BB aerosols from flaming burning of savanna at an older age (~4 days and >7 days).

Indication of a full life picture:

1. BrC initially contributes to a minor fraction of total absorption and undergoes a net enhancement by photochemical aging at least within the first 12 h. A following BrC net loss coupled with the decreasing AAE and MAC_{OA} is expected.

➢ Opposite BrC behaviours compared with BB in other field studies



2. SSA: Initial increase stage, followed by a decrease likely due to OA loss

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Conclusions

- MOYA-2017 presented a half-day aging process of BB aerosols emitted from flaming burning of African savanna.
- Concurrent measurements of chemical composition, OA oxidation state, bulk aerosol size and BC mixing state reveal that the initial submicron aerosols changed dramatically.
- These observations provide new field results of BB aerosol optical evolution.
  - The AAE suggests an initial stage of BrC absorption enhancement after emission, which means more important BrC contribution from secondary OA rather than the primary emission reported in other BB regions. Different treatments of BrC properties and its evolution in different BB regions should be considered in future model studies.
  - The effect of aging on BC absorbing properties, represent by $E_{Abs\text{-}MAC}$, was quantified.
  - The SSA had an initial increase stage, followed by a decrease likely due to OA loss with aging.