

A New Simplified Parameterization of Secondary Organic Aerosol in the Community Earth System Model Version 2 (CESM2)

Duseong S. Jo¹, Simone Tilmes¹, Louisa K. Emmons¹, Siyuan Wang², and Francis Vitt¹

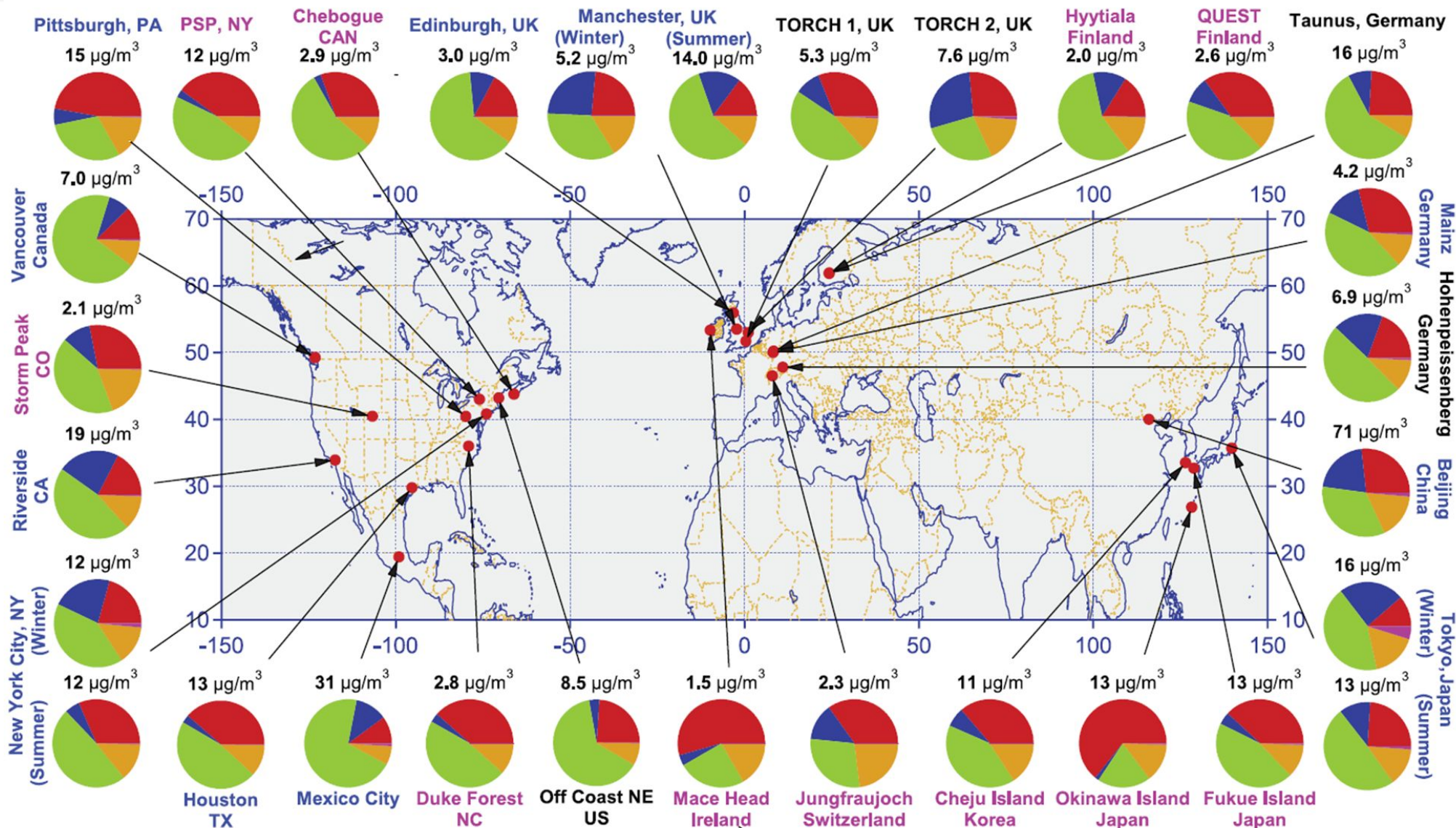
- 1) NCAR ACOM
- 2) NOAA CSL

January 30, 2023
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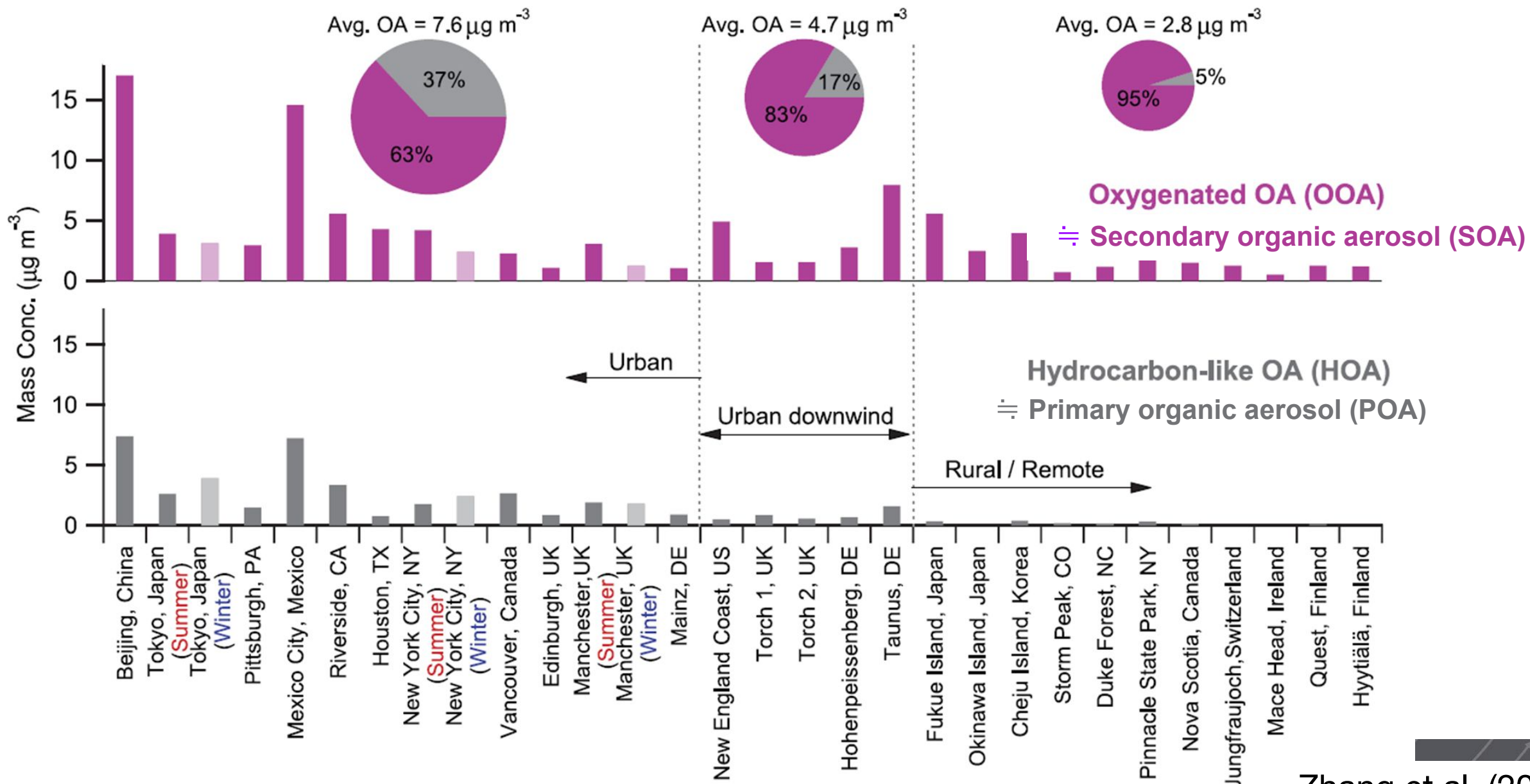


Organic aerosol contributes substantial mass fractions of submicron aerosols

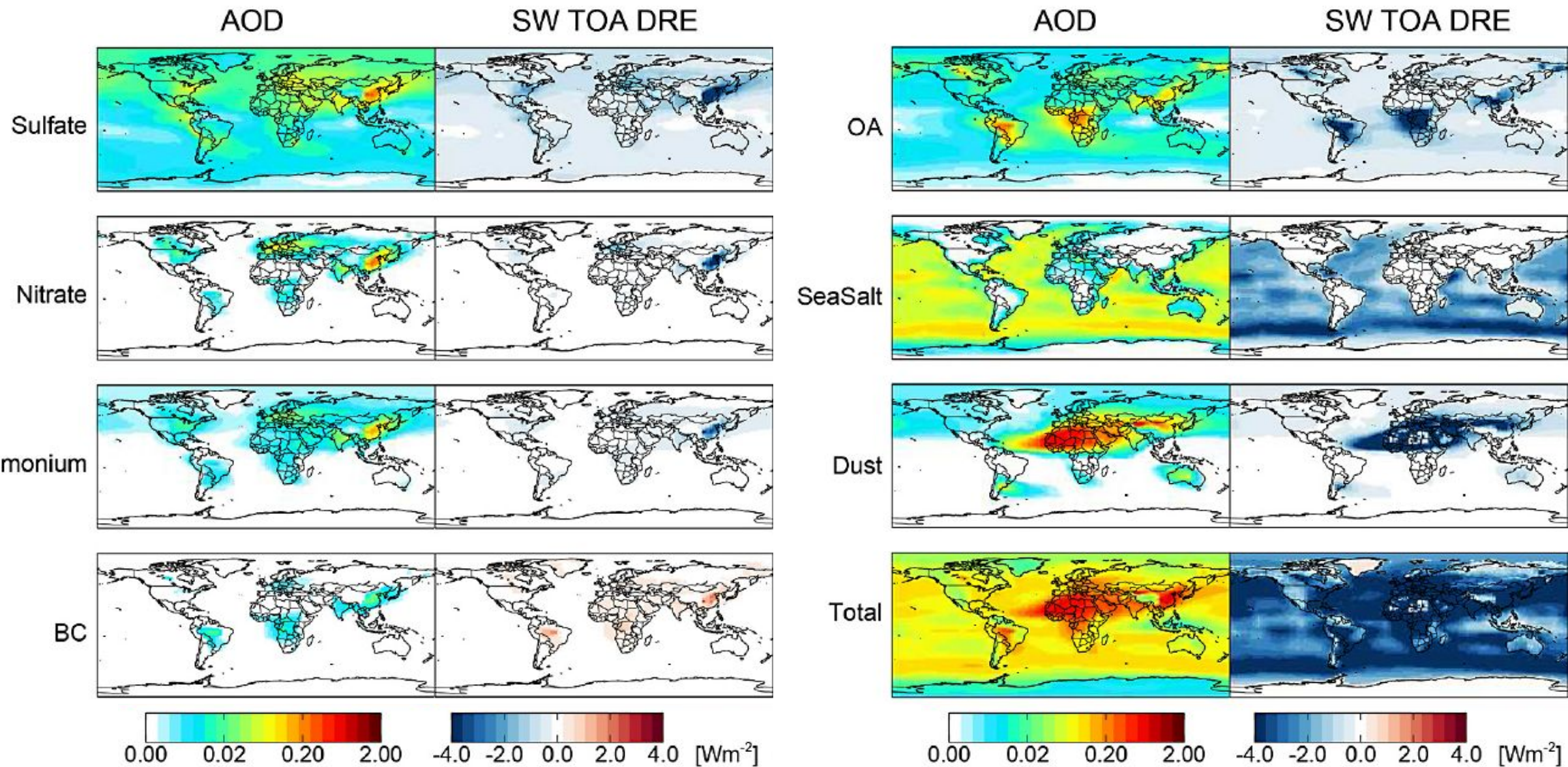
Organics
Sulfate
Nitrate
Ammonium
Chloride



Secondary organic aerosol (SOA) is accounting for 63 – 95% of the total OA



Organic aerosol is also important in terms of the Earth's radiation balance



Heald et al. (2014)

SOA scheme not only affects SOA burden, but POM (or POA) and BC in CESM2

Table 5 CAM SOA CAM-chem SOA
Aerosol Burden Separated Into Different Modes, Preindustrial Conditions

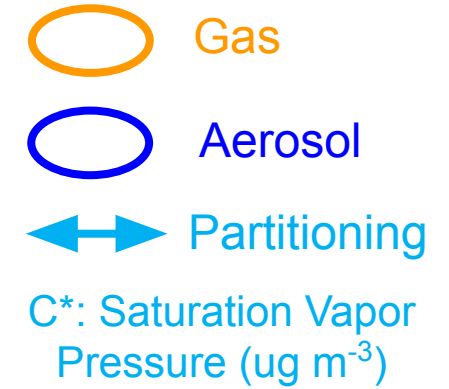
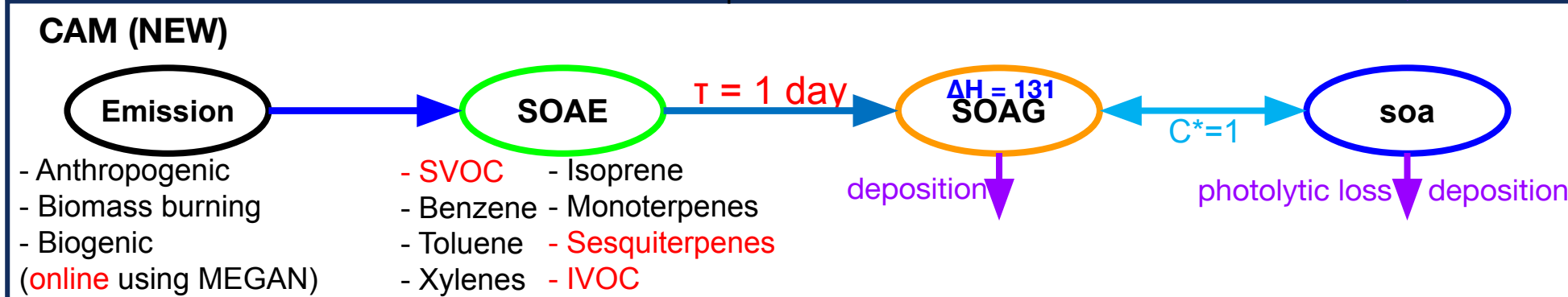
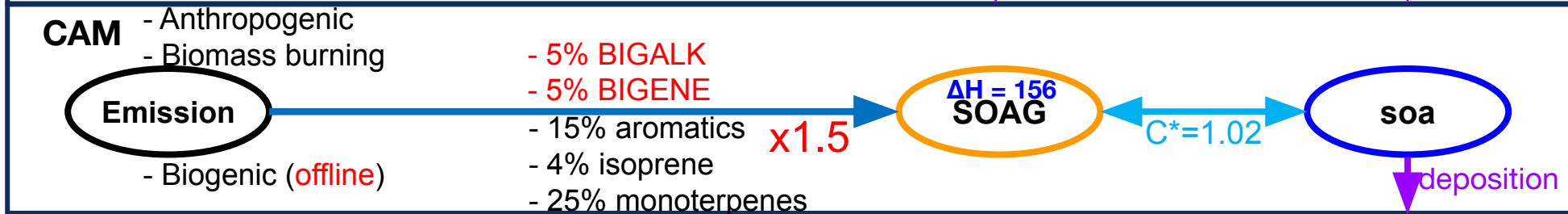
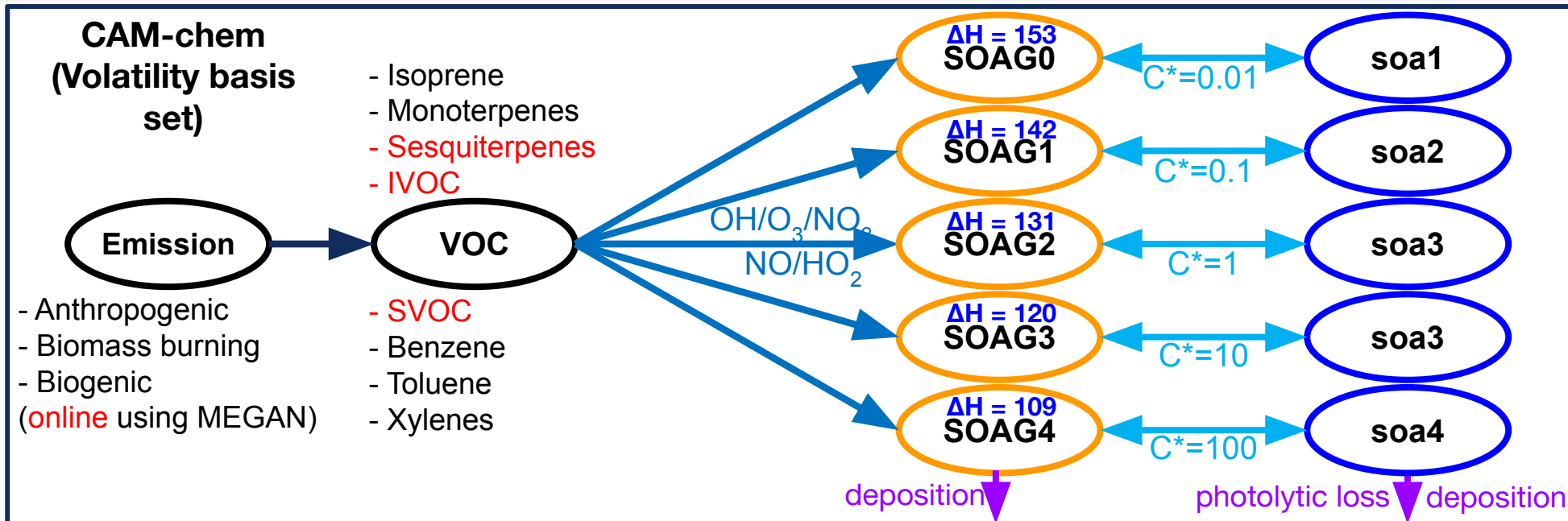
SOA	WACCM6-SOAG	WACCM6-VBSext	Difference	Rel diff (%)
Burden (Tg)	0.915	0.791	0.124	13.53
Accumulation	0.907	0.785	0.123	13.51
Aitken	0.008	0.007	0.001	7.88
Burden (Tg) (<500 hPa)	0.526	0.421	0.105	19.95
POM	WACCM6-SOAG	WACCM6-VBSext	Difference	Rel diff (%)
Burden (Tg)	0.517	0.405	0.112	21.60
Accumulation	0.280	0.308	-0.028	-10.11
Primary carbon	0.237	0.097	0.140	59.00
Burden (Tg) (<500 hPa)	0.402	0.323	0.079	19.72
BC	WACCM6-SOAG	WACCM6-VBSext	Difference	Rel diff (%)
Burden (Tg)	0.051	0.042	0.009	17.68
Accumulation	0.029	0.032	-0.003	-11.41
Primary carbon	0.023	0.010	0.012	54.70
Burden (Tg) (<500 hPa)	0.040	0.033	0.007	16.86
SO4	WACCM6-SOAG	WACCM6-VBSext	Difference	Rel diff (%)
Burden (Tg S)	0.512	0.515	-0.003	-0.67
Accumulation	0.330	0.353	-0.022	-6.75
Aitken	0.019	0.017	0.002	8.71
Coarse	0.163	0.145	0.017	10.59
Burden (Tg S) (<500 hPa)	0.089	0.088	0.001	1.00

Primary organic matter (POM) and Black carbon (BC) increased by ~20% when using the simplified SOA scheme compared to the VBS scheme (Tilmes et al., 2019)

Goal of this study

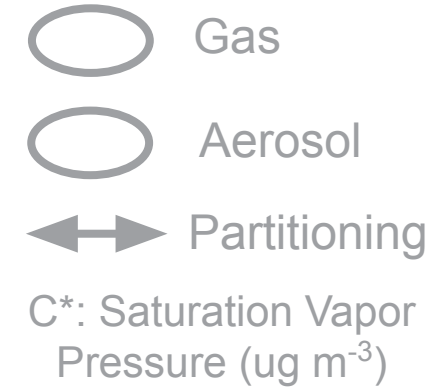
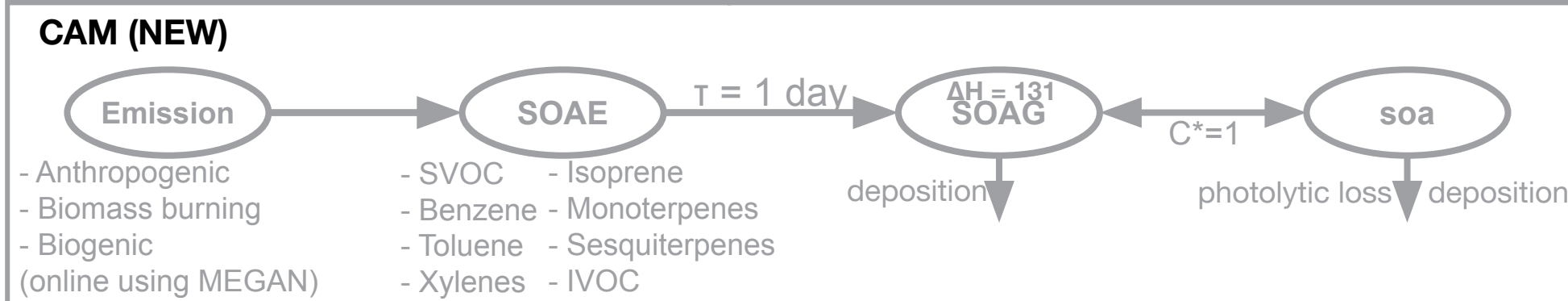
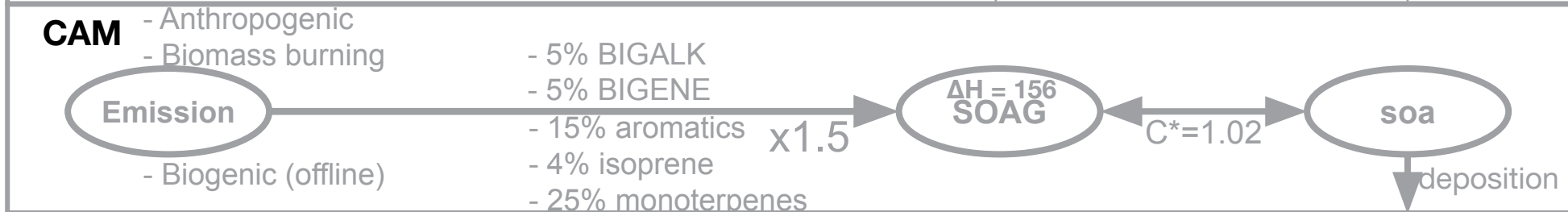
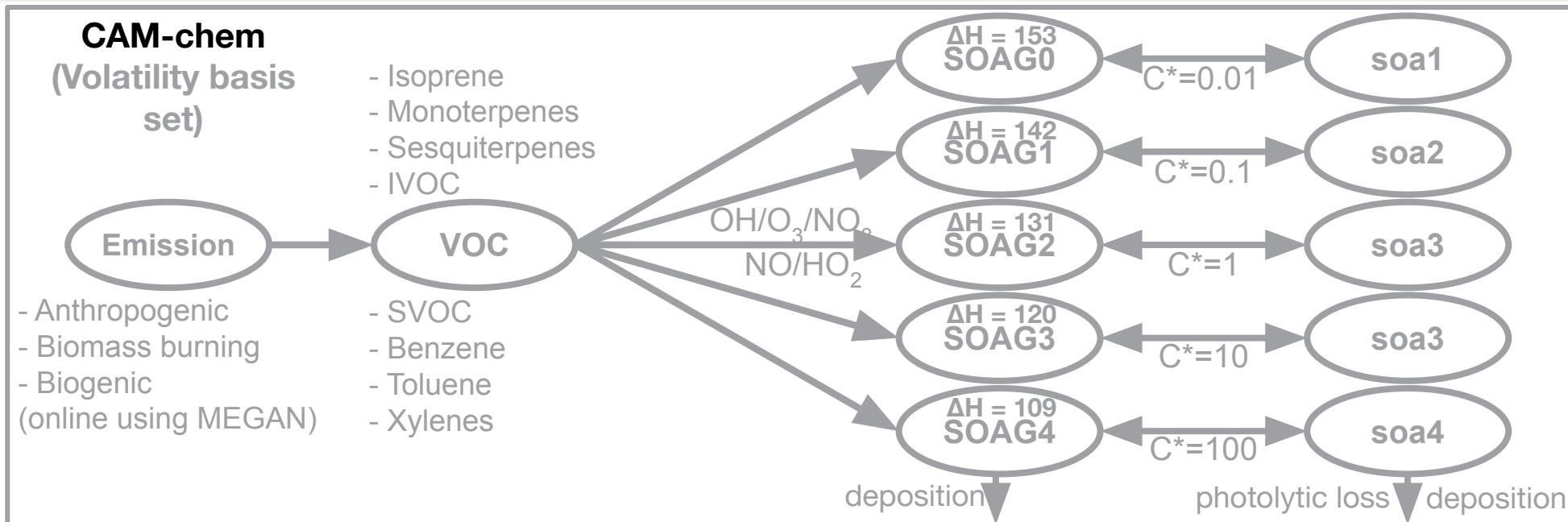
- (1) Consistent **SOA** concentrations between CAM and CAM-chem (and WACCM)
- (2) Consistent **BC** and **POM** concentrations between CAM and CAM-chem (and WACCM)
- (3) Consistent **radiation fields** between CAM and CAM-chem (and WACCM)

Secondary organic aerosol (SOA) in CAM and CAM-chem



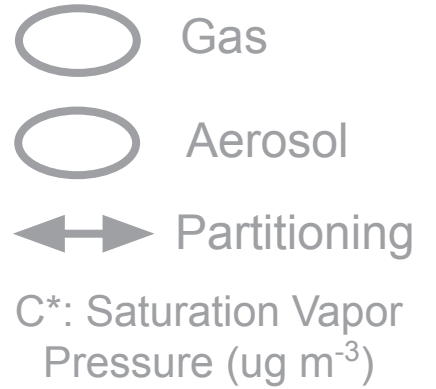
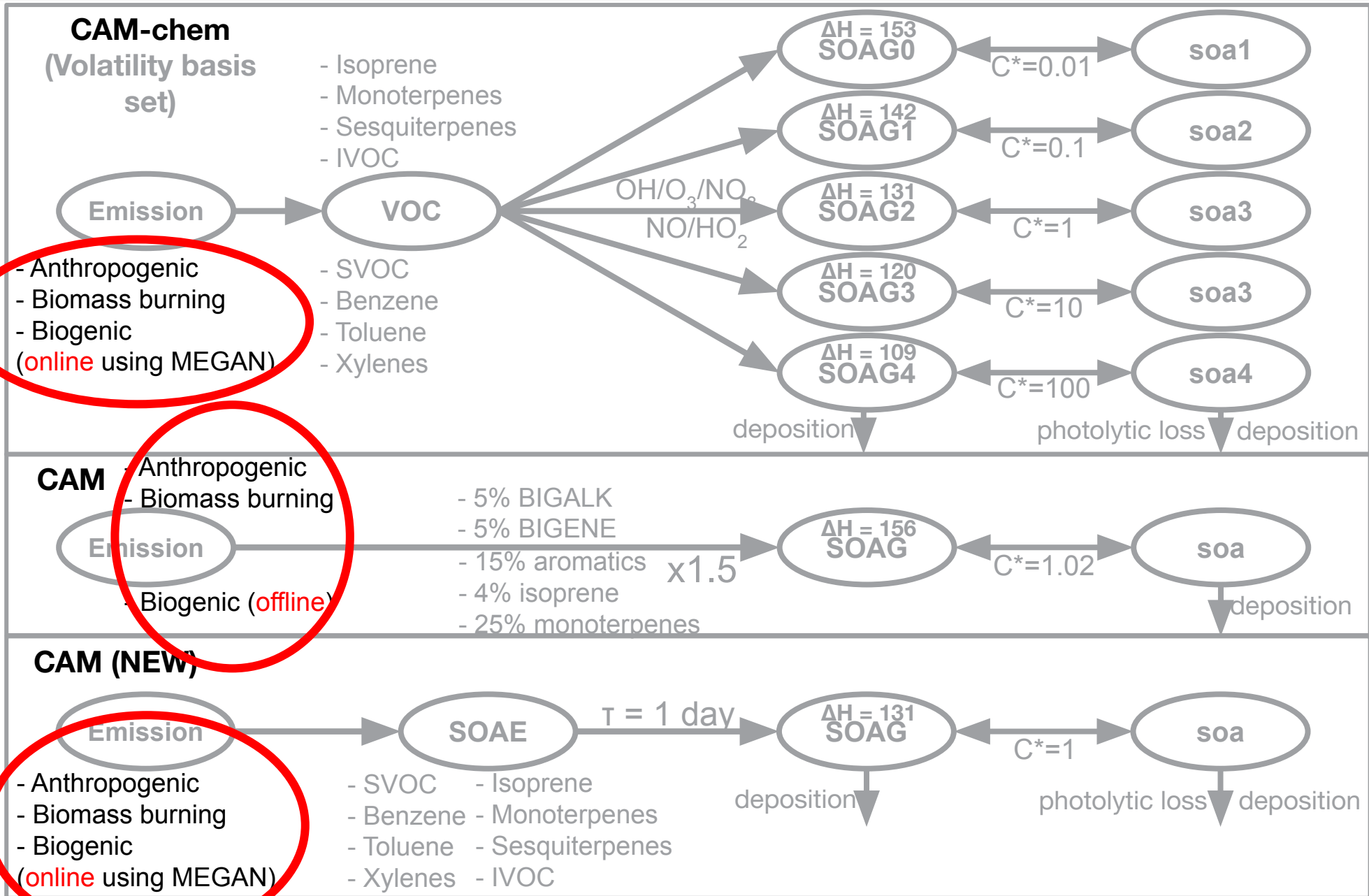
- Online vs offline biogenic emissions
- Different VOCs considered
- No VOC and oxidation process in CAM
- Different SOA yields, saturation vapor pressure, and enthalpy of vaporization
- Different number of SOA tracers
- Some loss processes are not considered in CAM

Secondary organic aerosol (SOA) in CAM and CAM-chem



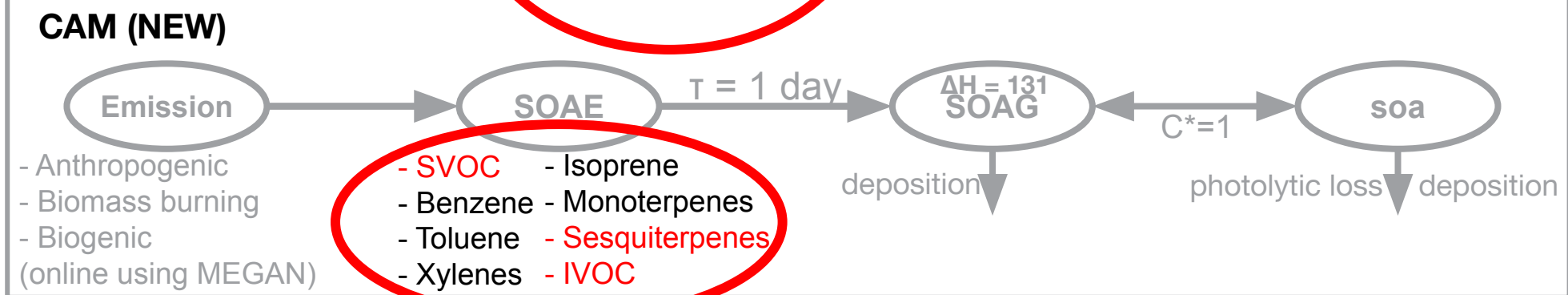
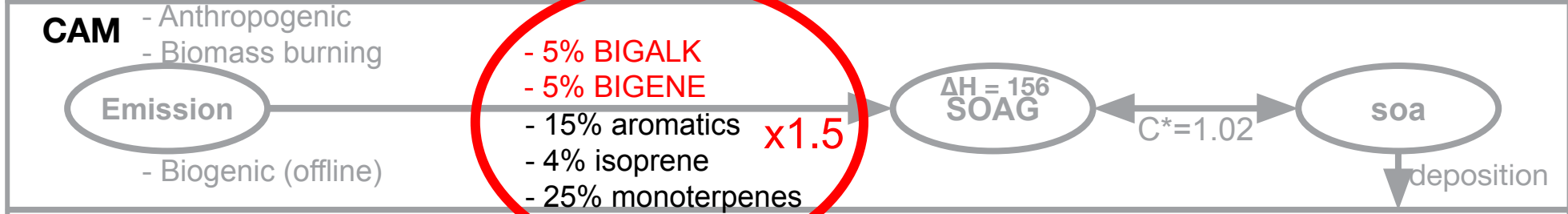
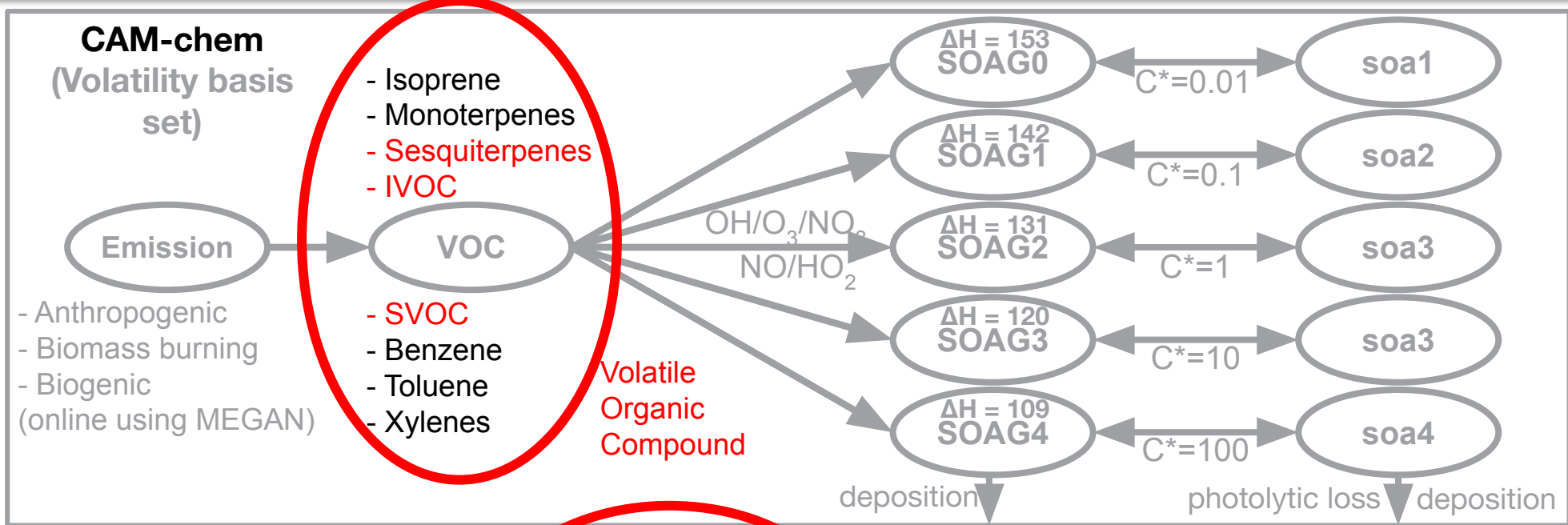
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Secondary organic aerosol (SOA) in CAM and CAM-chem



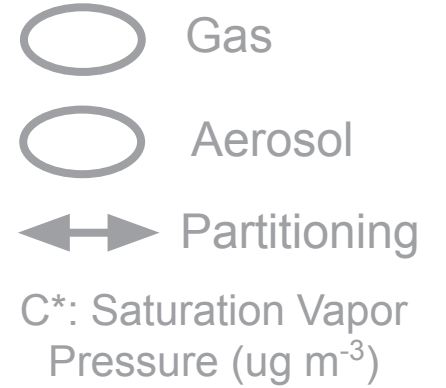
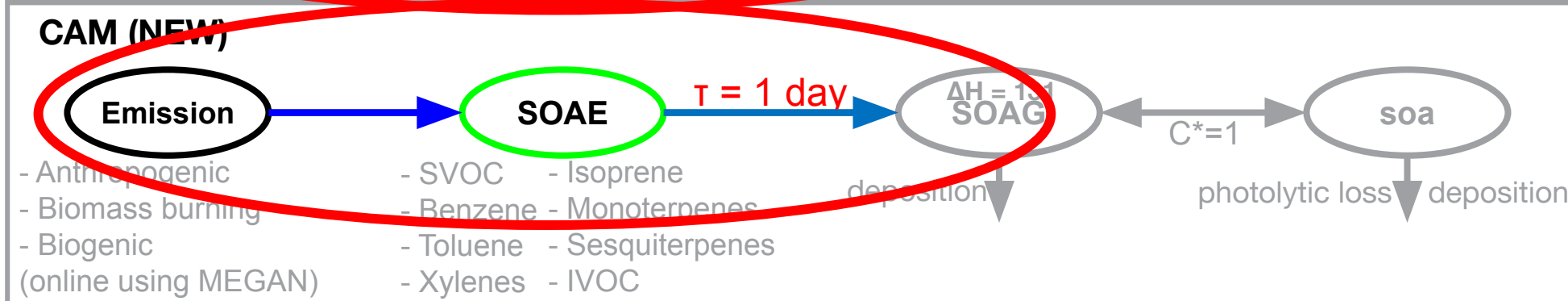
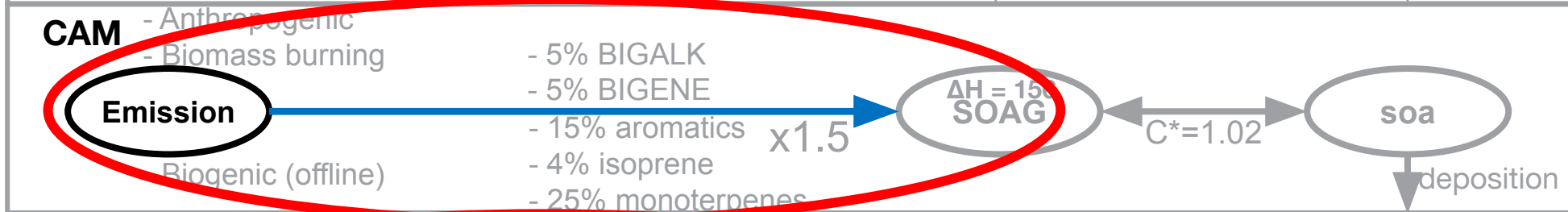
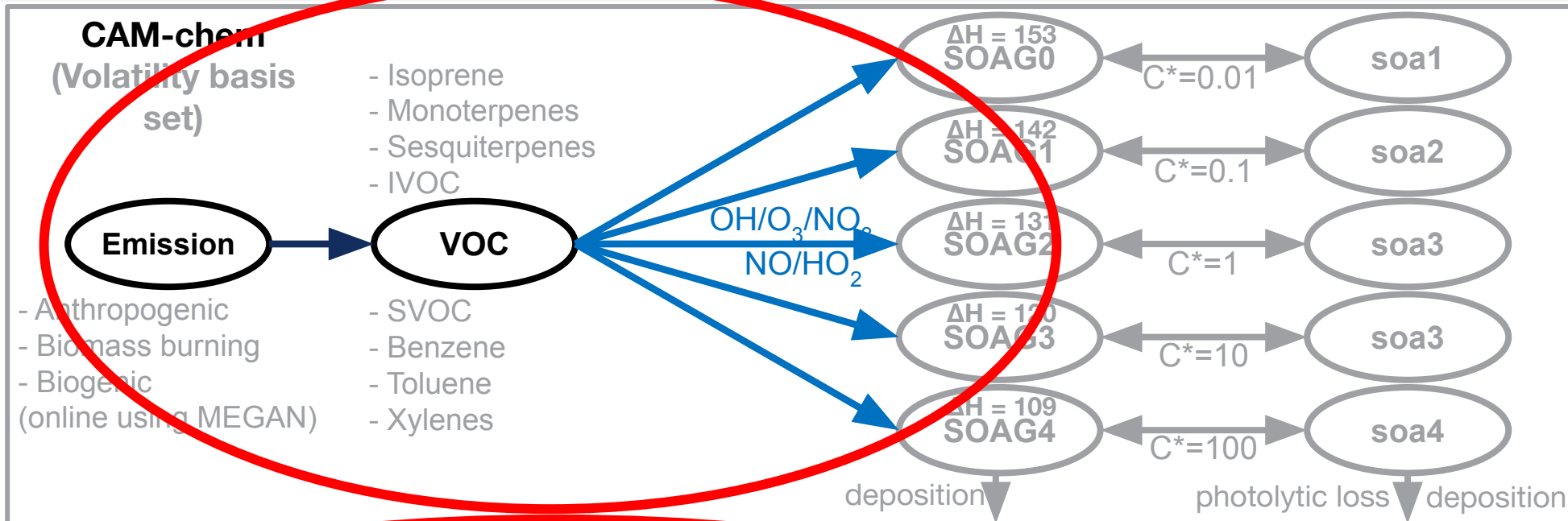
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Secondary organic aerosol (SOA) in CAM and CAM-chem



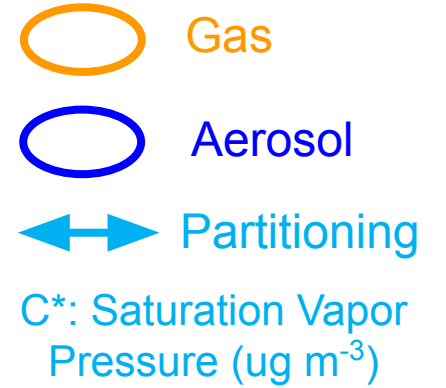
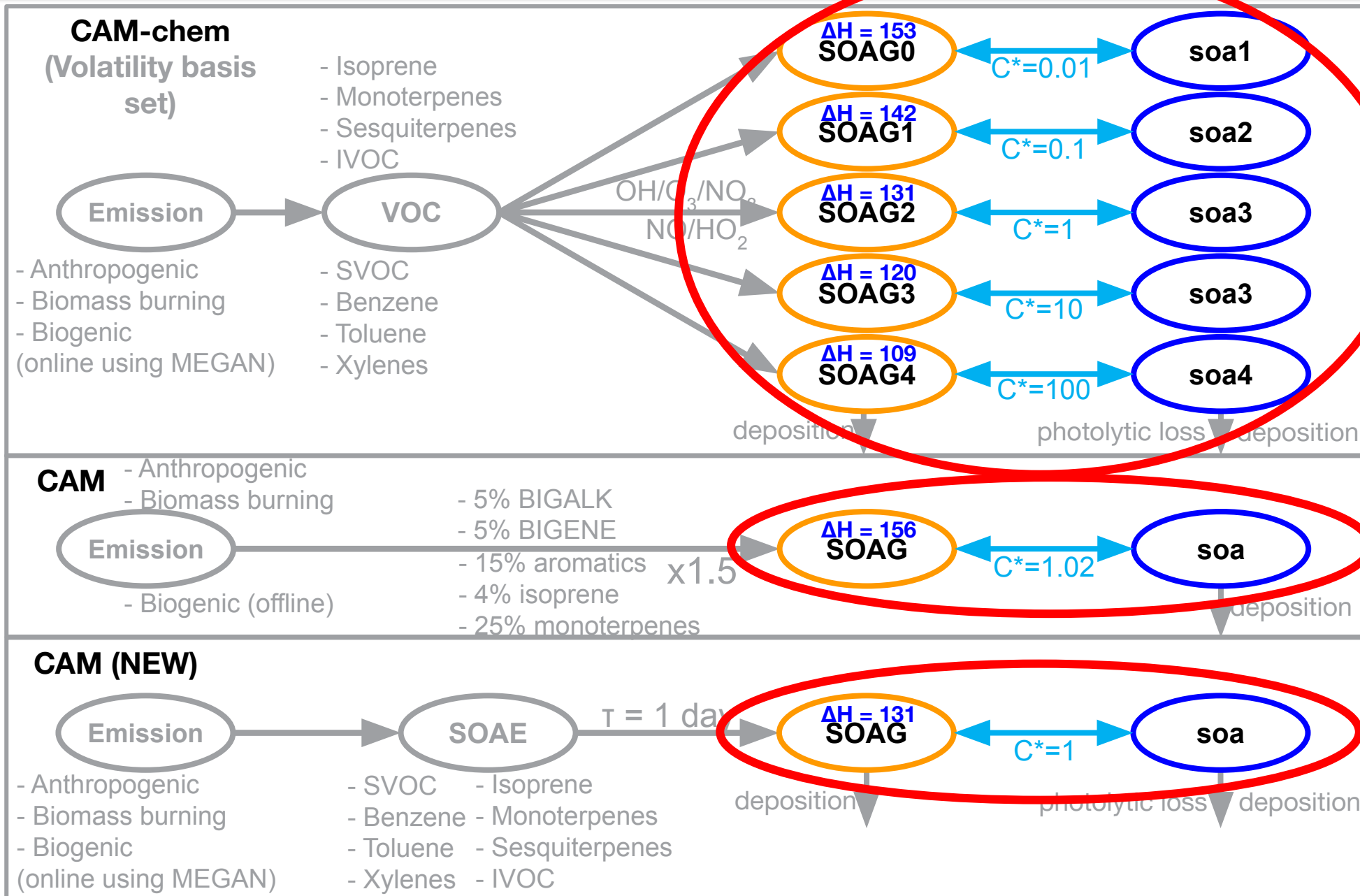
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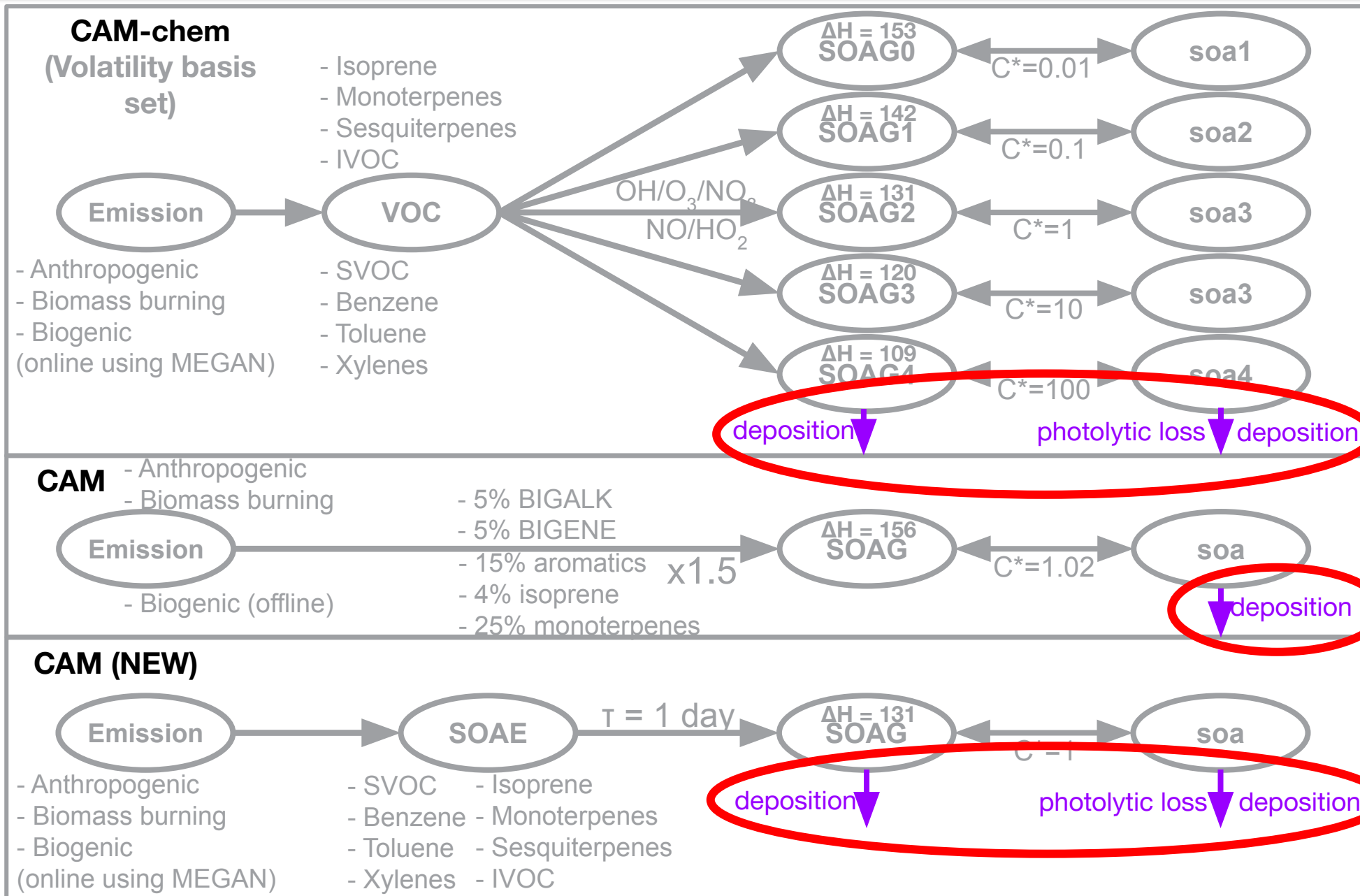
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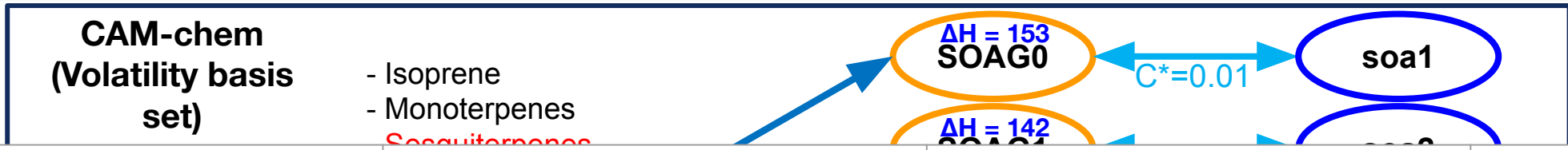
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Secondary organic aerosol (SOA) in CAM and CAM-chem

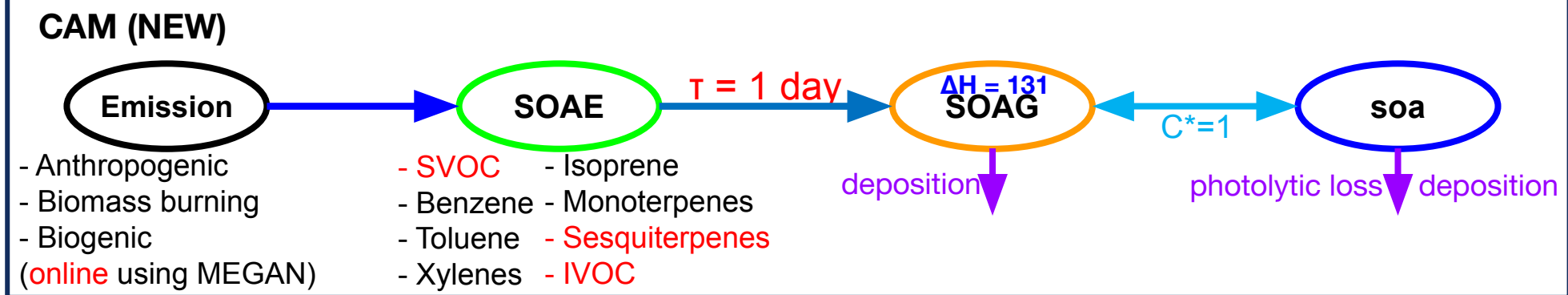
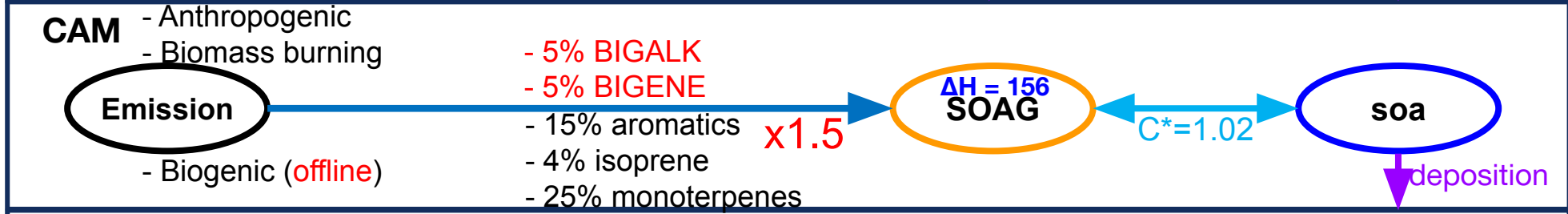


- Gas
- Aerosol
- ↔ Partitioning
- C*: Saturation Vapor Pressure (ug m⁻³)
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Secondary organic aerosol (SOA) in CAM and CAM-chem

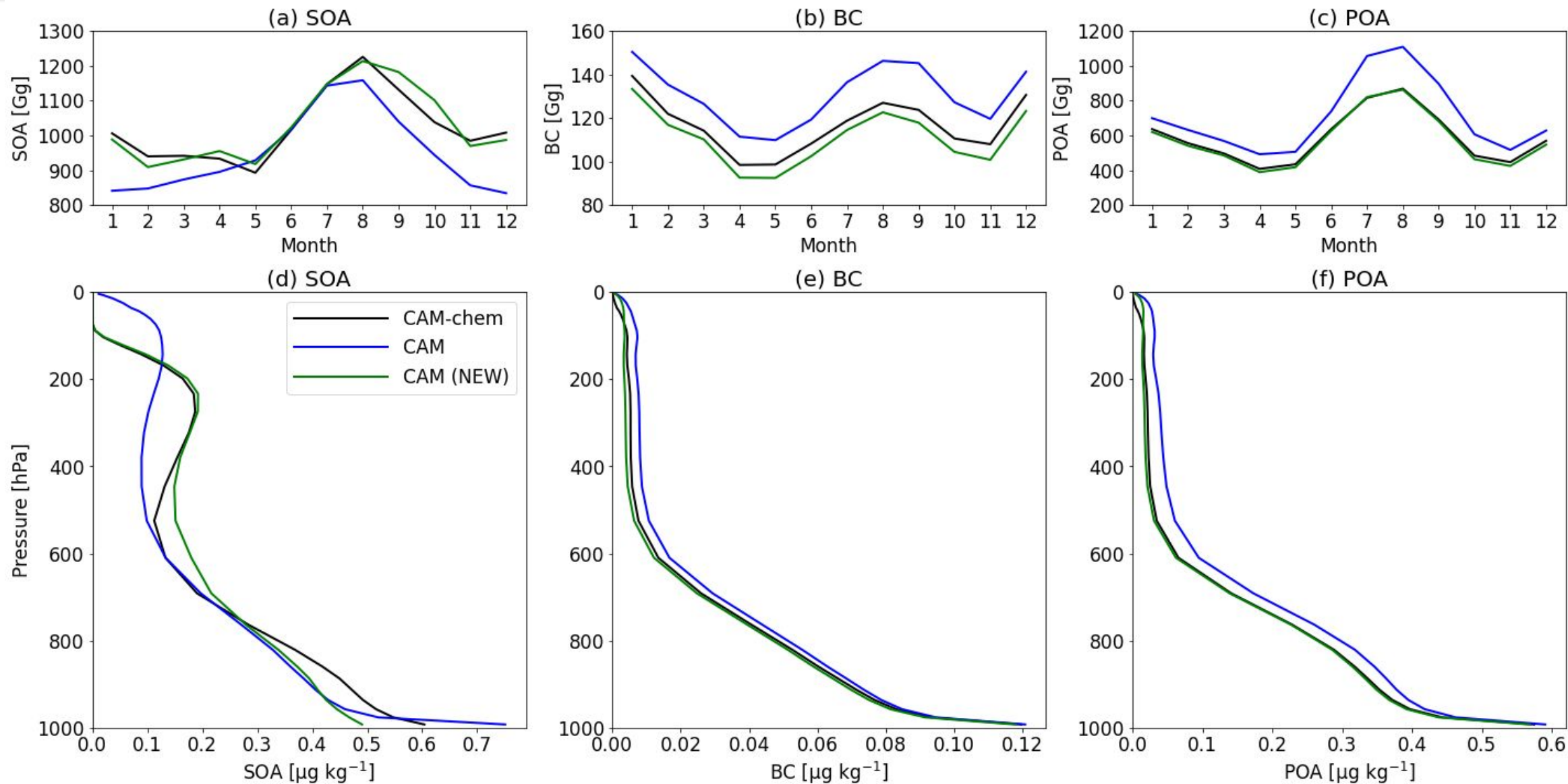


	CAM-chem	CAM	CAM (NEW)
Computational cost (pe-hrs / simulated_year)	7933 (7783 - 8083)	2398 (2353 - 2448)	2455 (2414 - 2501)

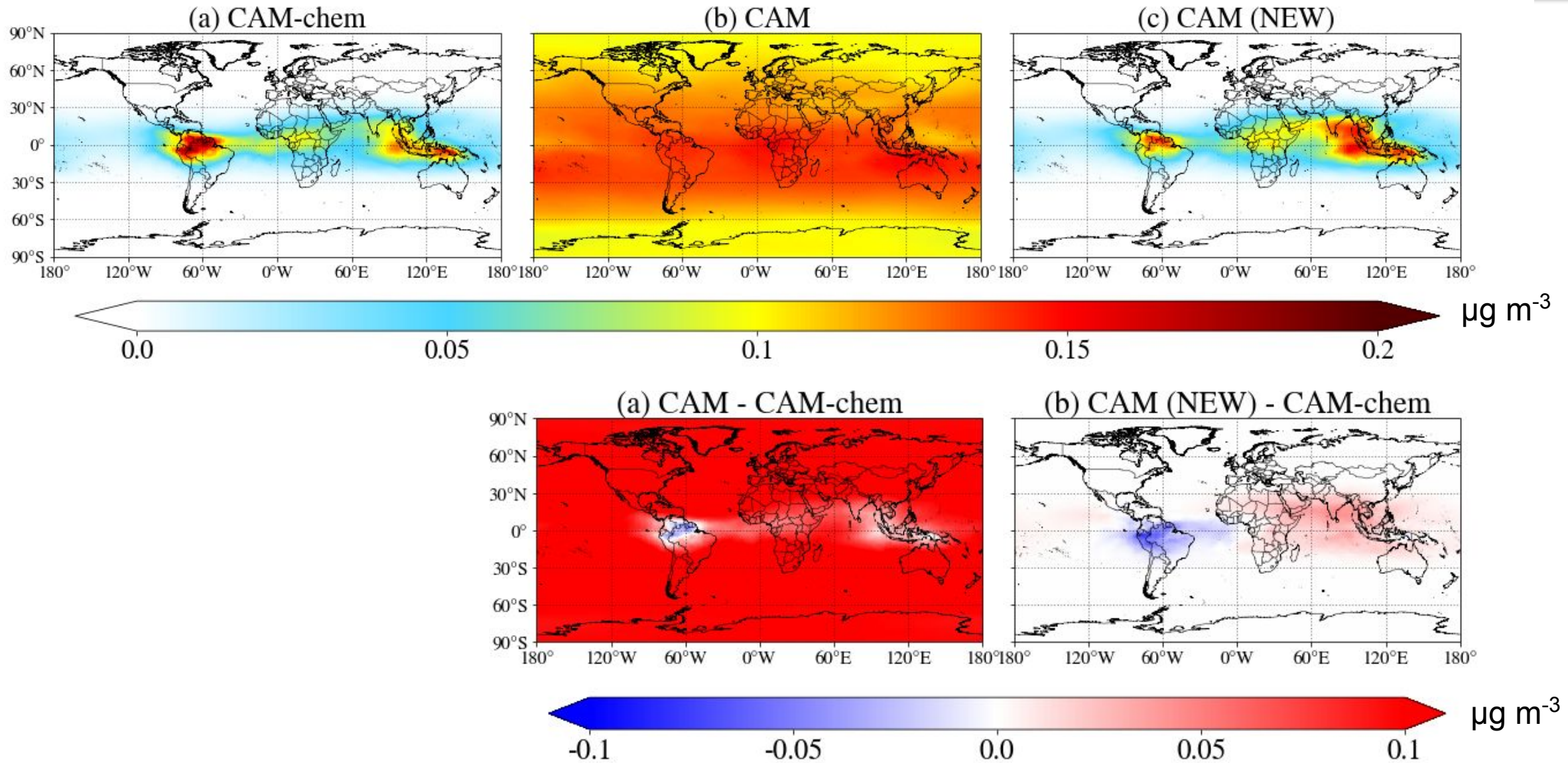


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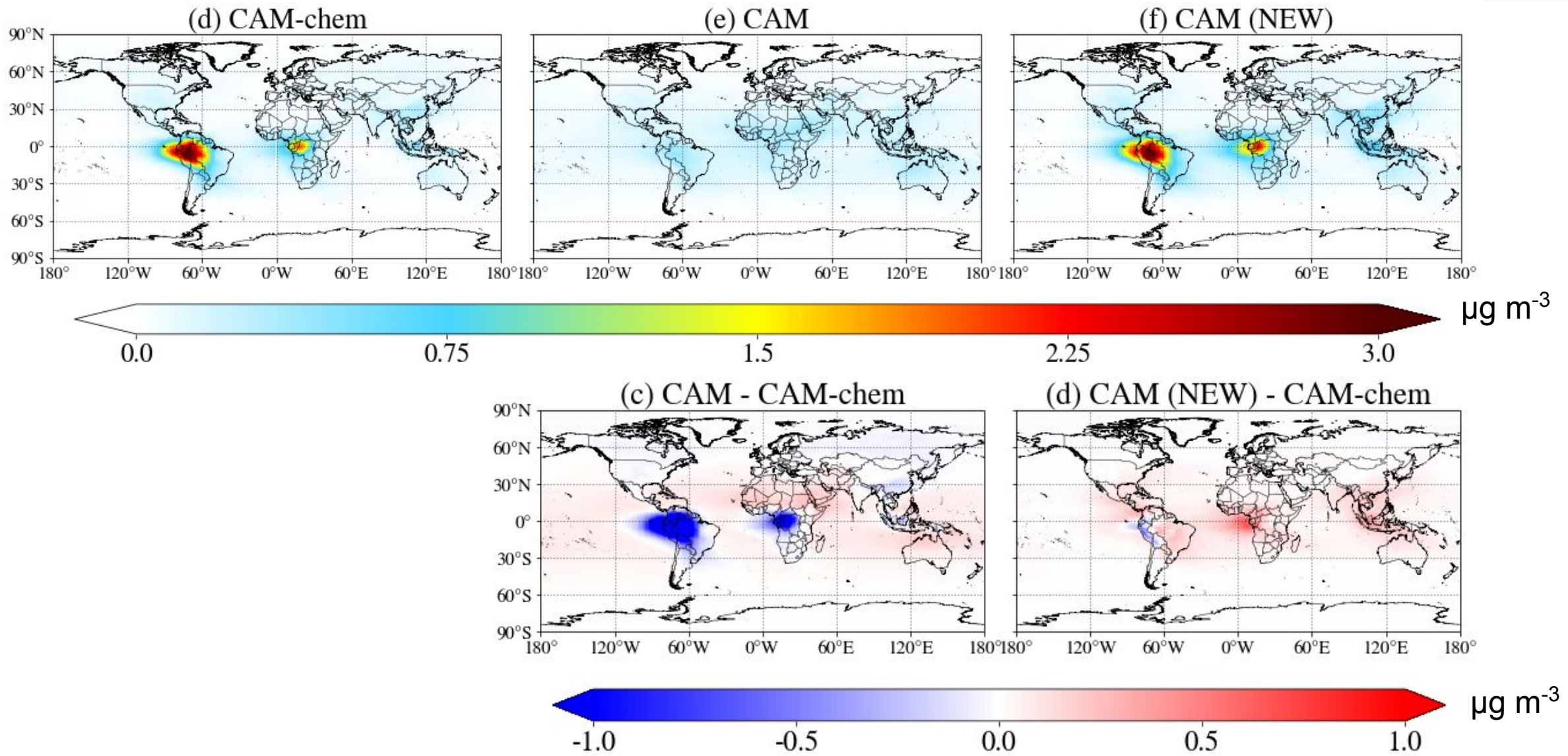
Seasonalities and vertical distributions of SOA, BC, and POA (or POM) in 2013 (nudged)



Spatial distributions of SOA at ~100 hPa

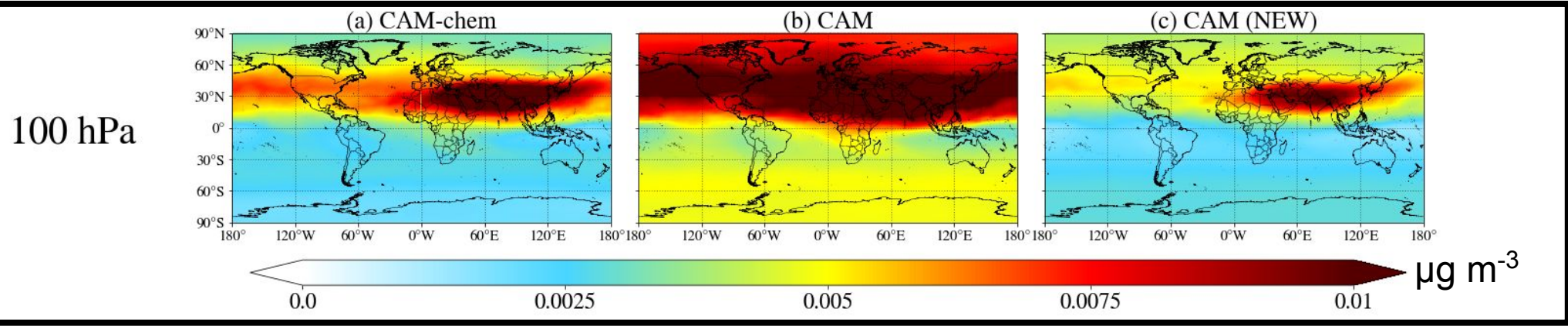


Spatial distributions of SOA at ~500 hPa

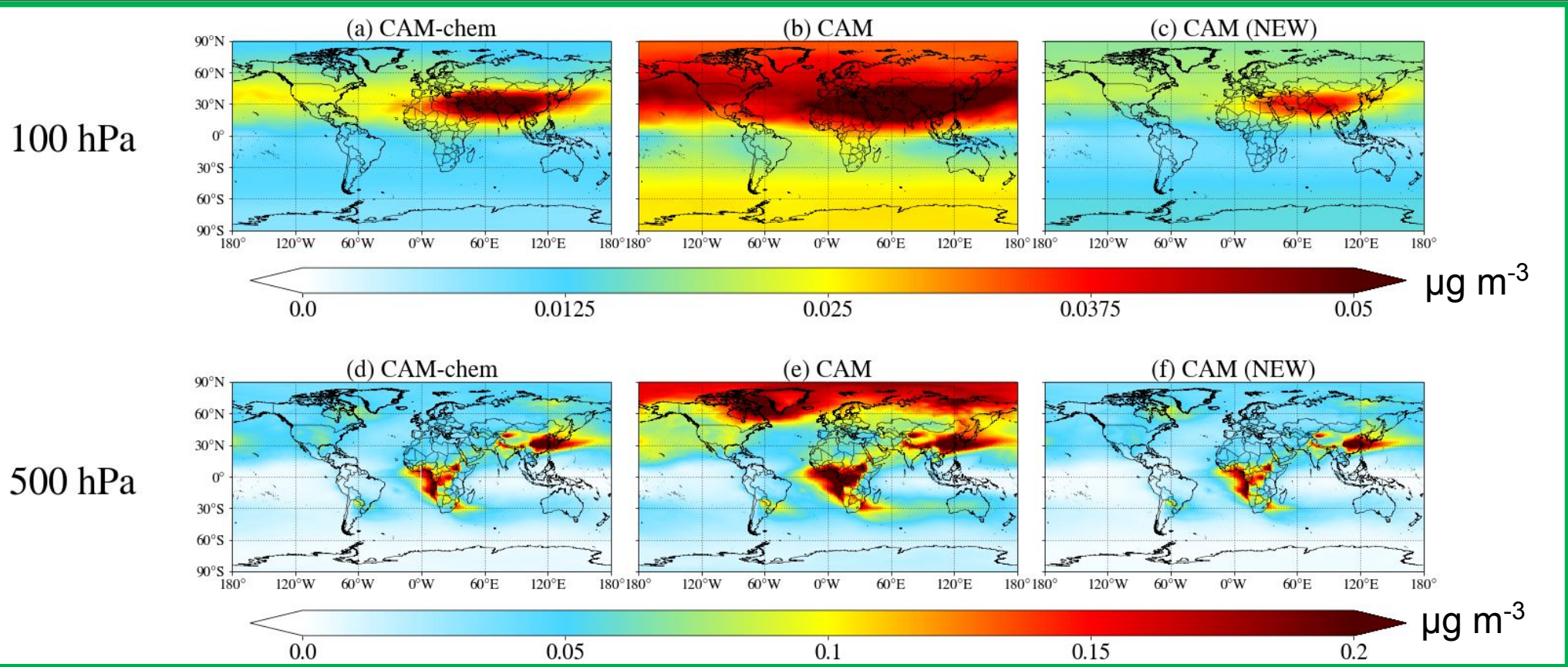


Spatial distributions of BC and POA at ~100 hPa and ~500 hPa

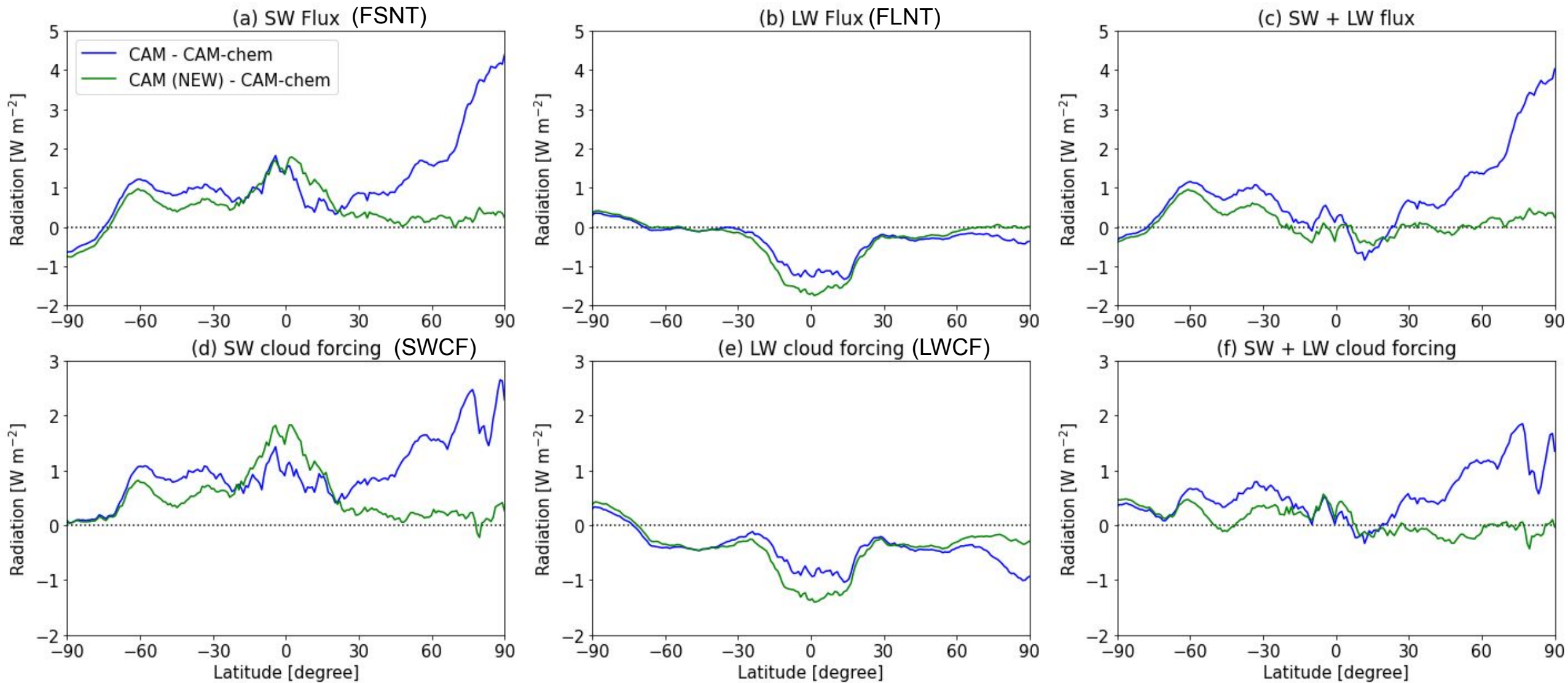
Black Carbon (BC)



Primary Organic Aerosol (POA)

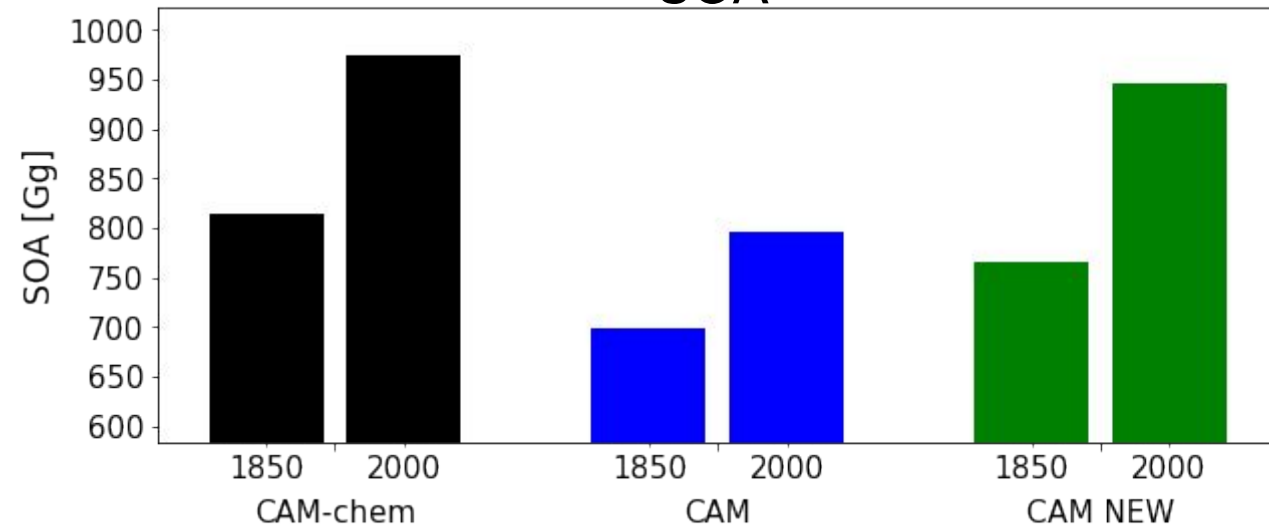


Zonal averages of the radiation difference in 2013 between CAM and CAM-chem



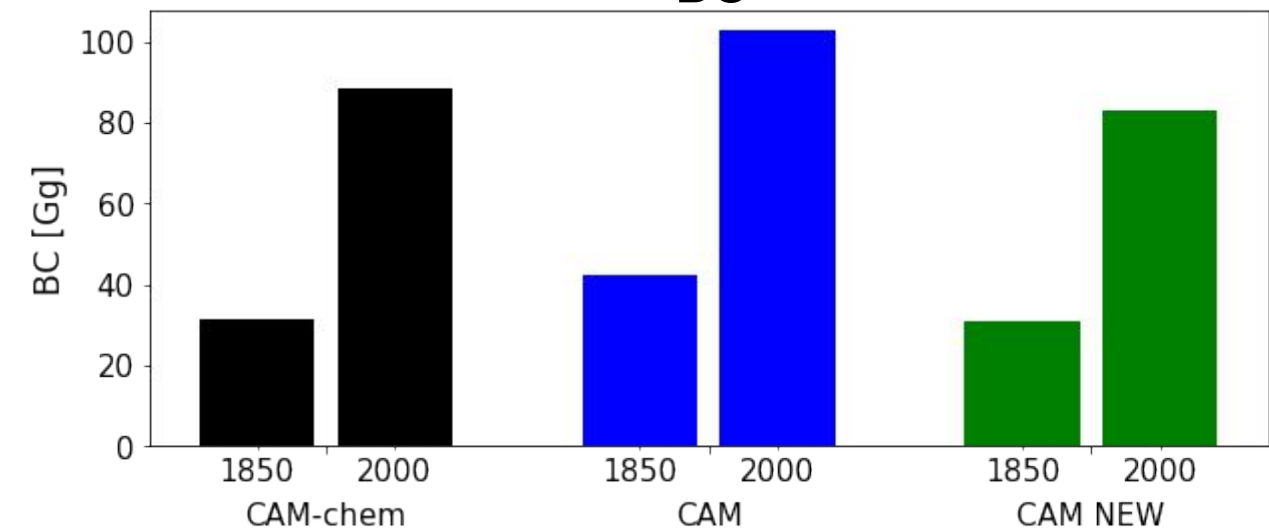
Historical run results (1850s and 2000s) - Aerosol burdens

SOA

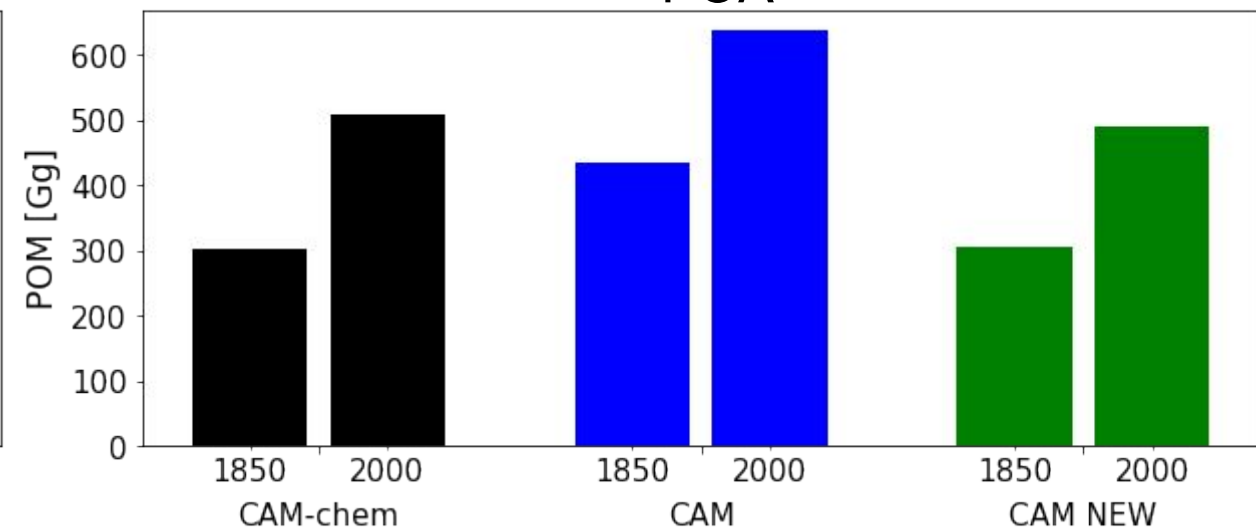


- Same conclusion for historical simulations
- More consistent results are obtained with the new SOA scheme in CAM

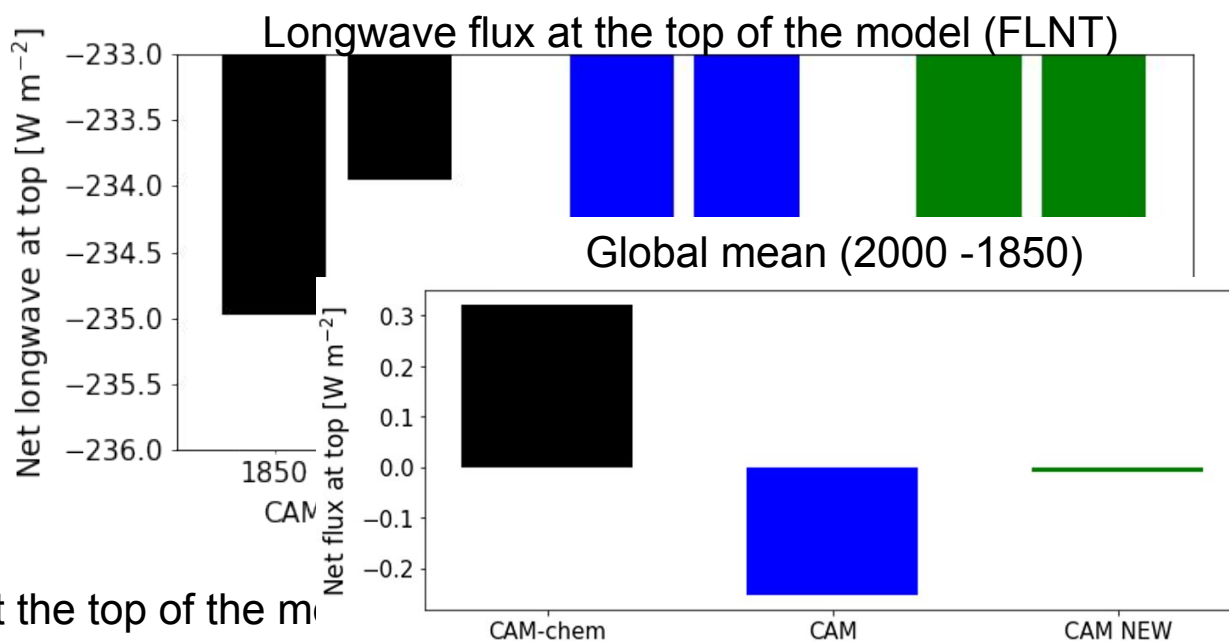
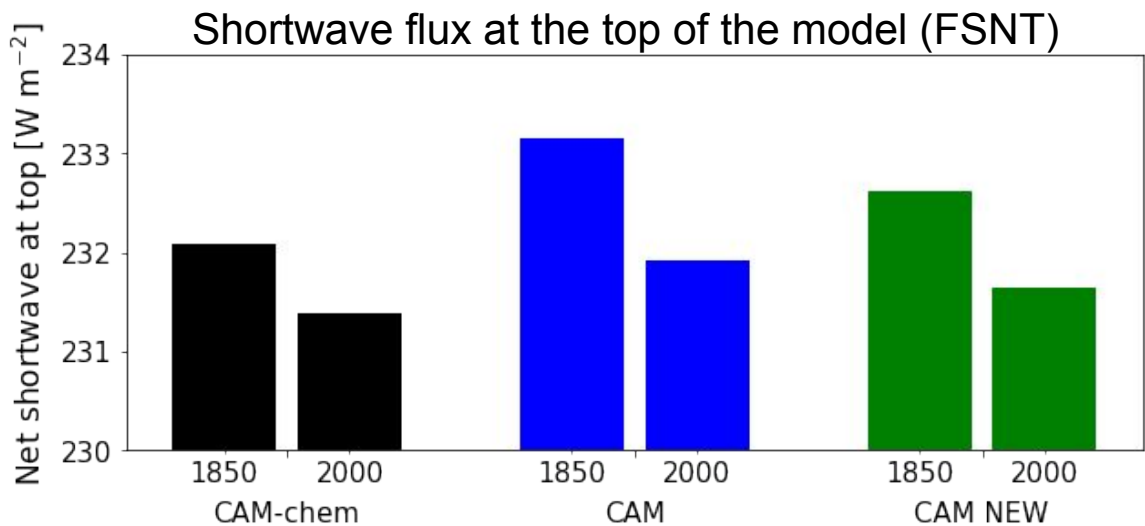
BC



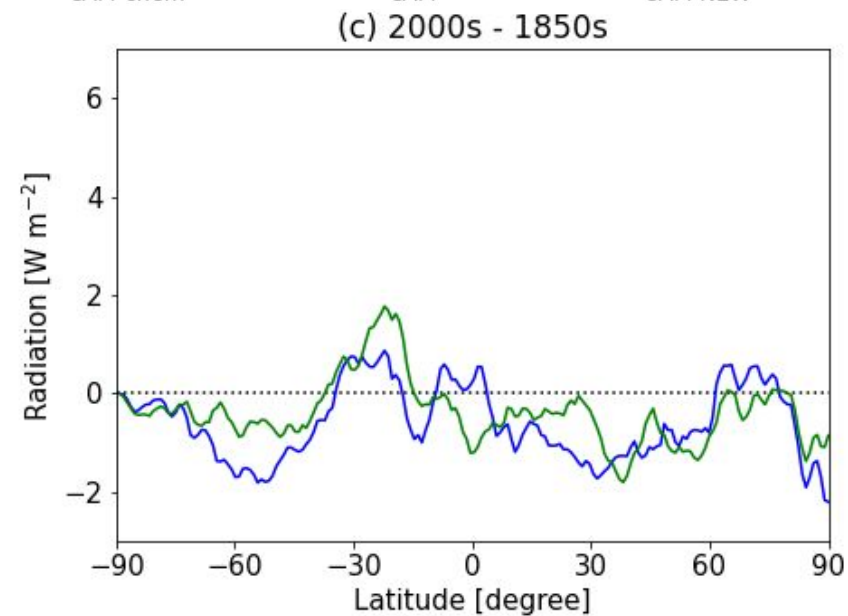
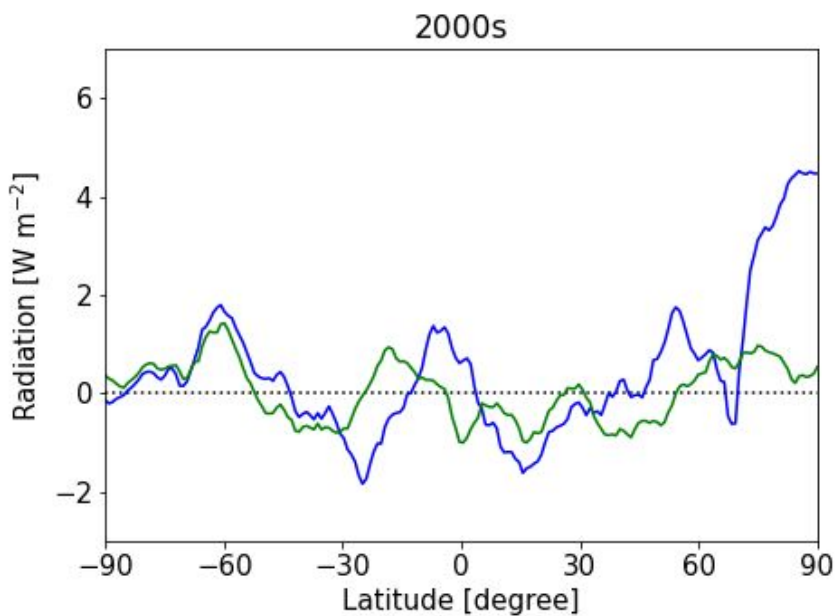
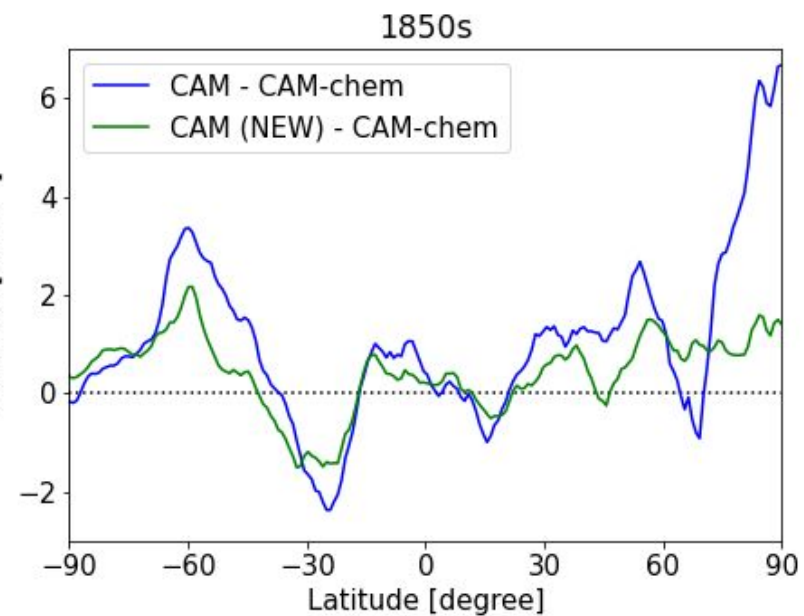
POA



Zonal averages of the radiation (SW + LW) difference in historical runs between CAM and CAM-chem



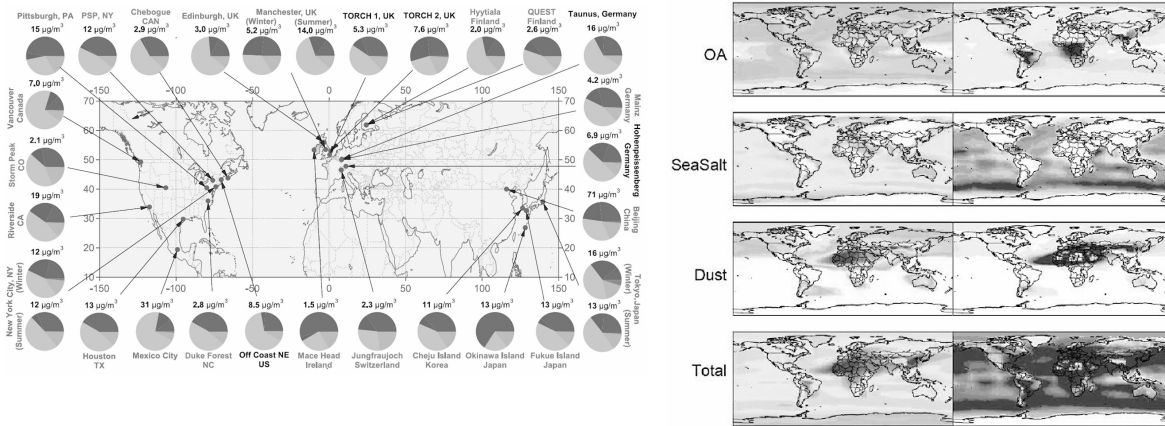
Shortwave + Longwave flux at the top of the model



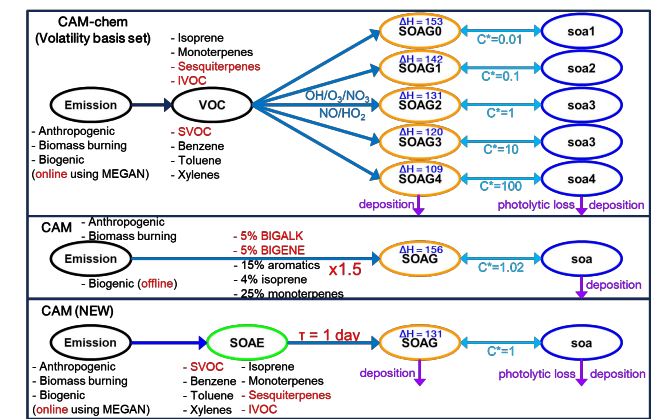
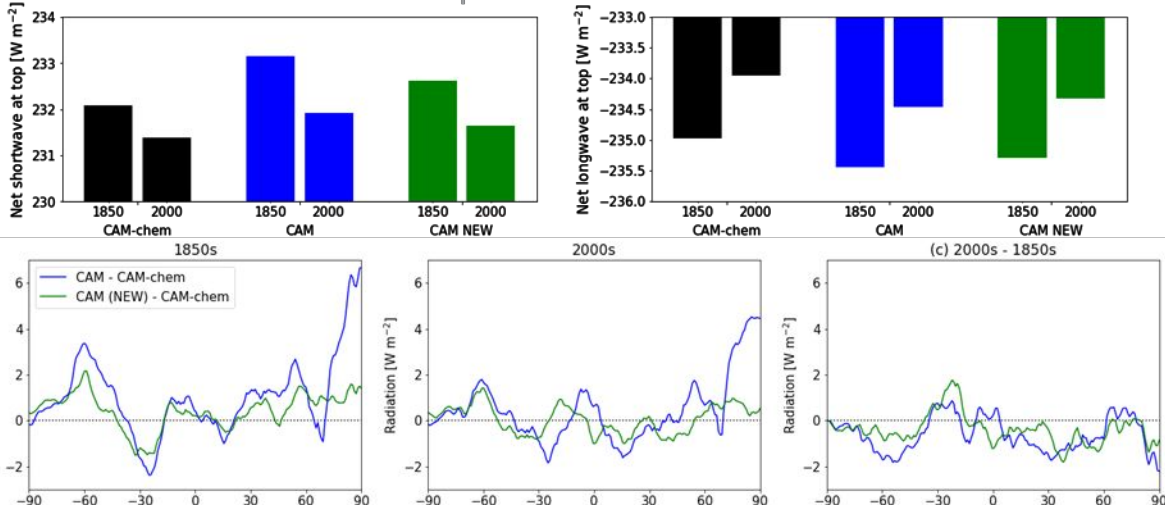
Summary

Organic aerosols represent a significant fraction of aerosols in the atmosphere and are important for Earth's radiation balance.

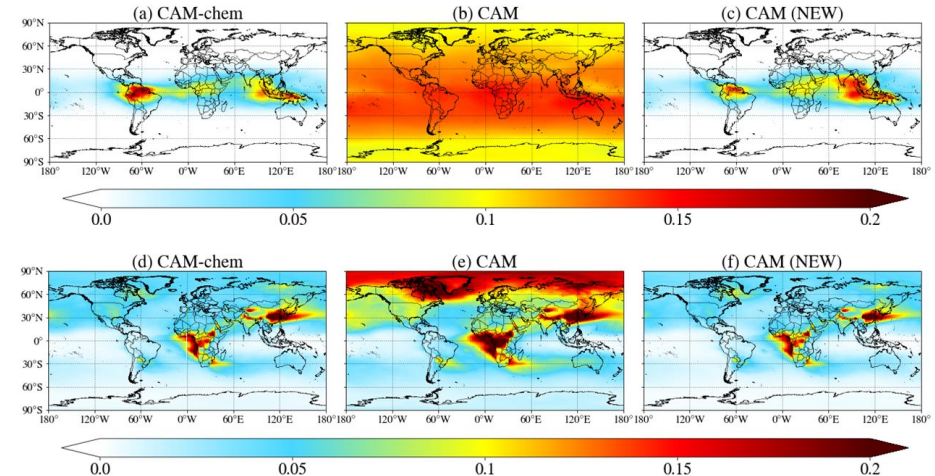
The new simplified SOA scheme has been developed for the consistent aerosol and radiation fields between CAM and CAM-chem, without adding much computational cost.



Compared to CAM-chem, the high bias of radiative flux in the Arctic region is significantly reduced for both nudged and free-running CAM simulations with the new parameterization.



With the new SOA scheme, more consistent temporal and spatial distributions of SOA, BC, and POA have been obtained.



Thank you!