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Constraints on black carbon lifetime inferred from a global set of aircraft observations

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ARTICLE OPEN

Short Black Carbon lifetime inferred from a global set of aircraft observations

Marianne T. Lund[1], Bjørn H. Samset[1], Ragnhild B. Skeie[1], Duncan Watson-Parris[2], Joseph M. Katich[3,4], Joshua P. Schwarz[3] and Bernadett Weinzierl[5]

Black Carbon (BC) aerosols substantially affect the global climate. However, accurate simulation of BC atmospheric transport remains elusive, due to shortcomings in modeling and a shortage of constraining measurements. Recently, several studies have compared simulations with observed vertical concentration profiles, and diagnosed a global-mean BC atmospheric residence time of <5 days. These studies have, however, been focused on limited geographical regions, and used temporally and spatially coarse model information. Here we expand on previous results by comparing a wide range of recent aircraft measurements from multiple regions, including the Arctic and the Atlantic and Pacific oceans, to simulated distributions obtained at varying spatial and temporal resolution. By perturbing BC removal processes and using current best-estimate emissions, we confirm a constraint on the global-mean BC lifetime of <5.5 days, shorter than in many current global models, over a broader geographical range than has so far been possible. Sampling resolution influences the results, although generally without introducing major bias. However, we uncover large regional differences in the diagnosed lifetime, in particular in the Arctic. We also find that only a weak constraint can be placed in the African outflow region over the South Atlantic, indicating inaccurate emission sources or model representation of transport and microphysical processes. While our results confirm that BC lifetime is shorter than predicted by most recent climate models, they also cast doubt on the usability of the concept of a "global-mean BC lifetime" for climate impact studies, or as an indicator of model skill.

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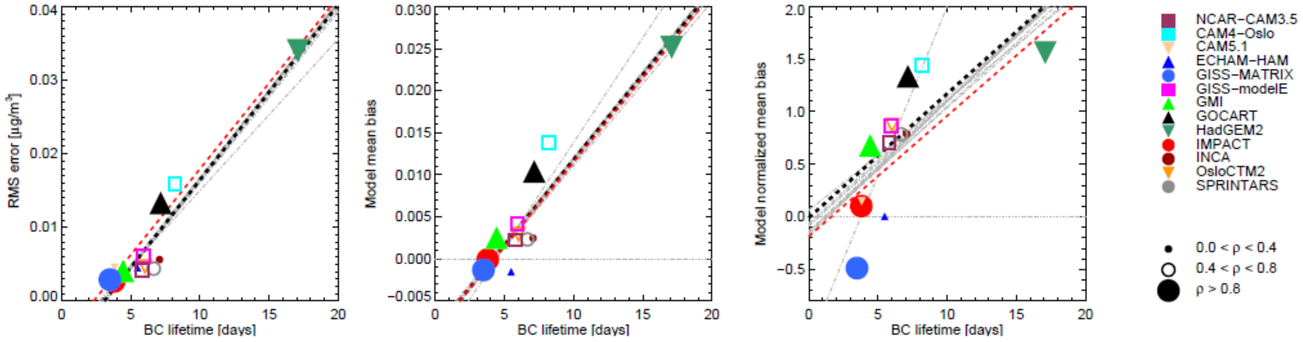
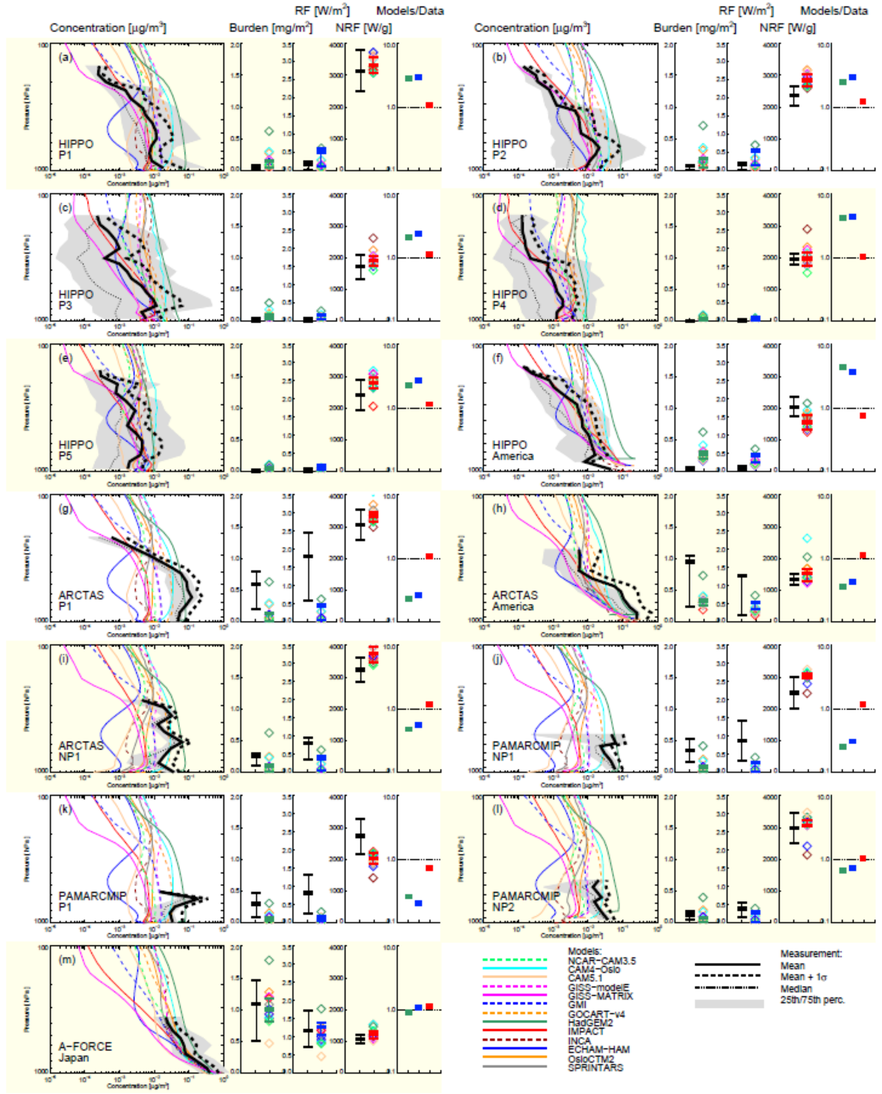
Recent studies suggest global BC lifetime < 4 days is a requirement for good agreement with aircraft observations over the Pacific Ocean

Modelled black carbon radiative forcing and atmospheric lifetime in AeroCom Phase II constrained by aircraft observations

B. H. Samset[1], G. Myhre[1], A. Herber[2], Y. Kondo[3], S.-M. Li[4], N. Moteki[3], M. Koike[3], N. Oshima[5], J. P. Schwarz[6,19], Y. Balkanski[7], S. E. Bauer[8], N. Bellouin[9,*], T. K. Berntsen[1], H. Bian[10], M. Chin[11], T. Diehl[11,20,**], R. C. Easter[12], S. J. Ghan[12], T. Iversen[13,21,22], A. Kirkevåg[13], J.-F. Lamarque[14], G. Lin[15], X. Liu[16], J. E. Penner[15], M. Schulz[13], Ø. Seland[13], R. B. Skeie[1], P. Stier[17], T. Takemura[18], K. Tsigaridis[8], and K. Zhang[12]





Does this finding hold in a broader geographical context?

Our study

BC vertical concentration distributions
on three-hourly, daily and monthly resolution, simulated by OsloCTM3 and ECHAM-HAM, against a range of aircraft observations from 2008–2017 (15 flight campaigns, 17 regions)

→ How well does modeled and measured vertical BC distribution agree?

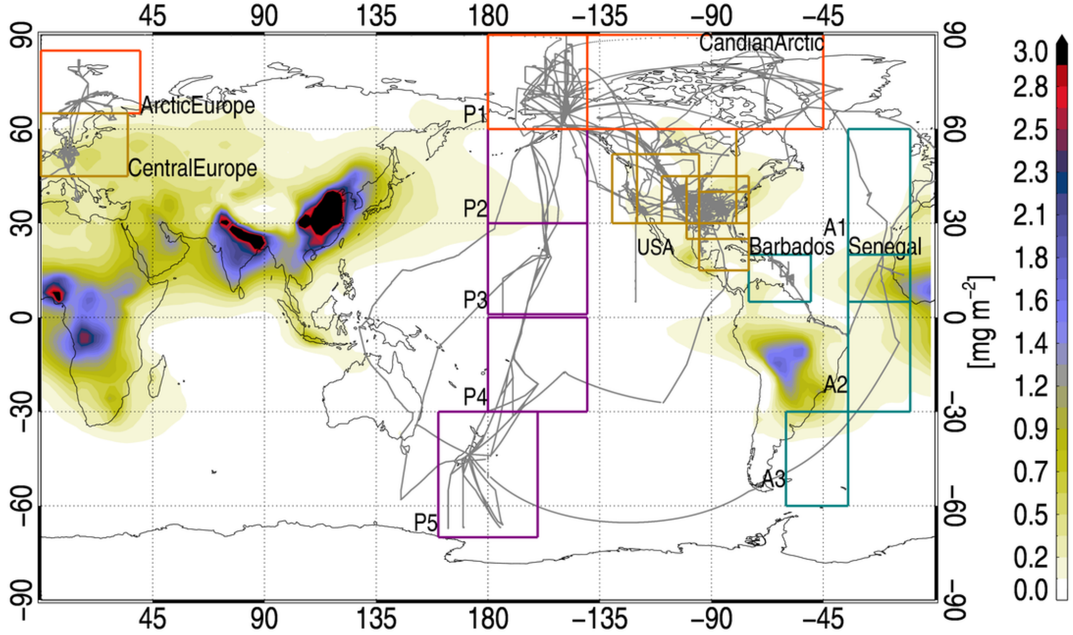
Modeled data sampled using online flight simulator, i.e., interpolation to flight track, and by averaging monthly mean model data over the entire area defined by respective region (i.e., as in Samset et al.)

→ Does sampling methodology influence the model evaluation?

Baseline configuration plus four sensitivity simulations with idealized changes to wet scavenging assumptions

→ Spread in global lifetime 3.2 – 8.1 days

→ What is the relationship between global BC lifetime and model skill?



Arctic
Atlantic Ocean
Pacific Ocean
Continental

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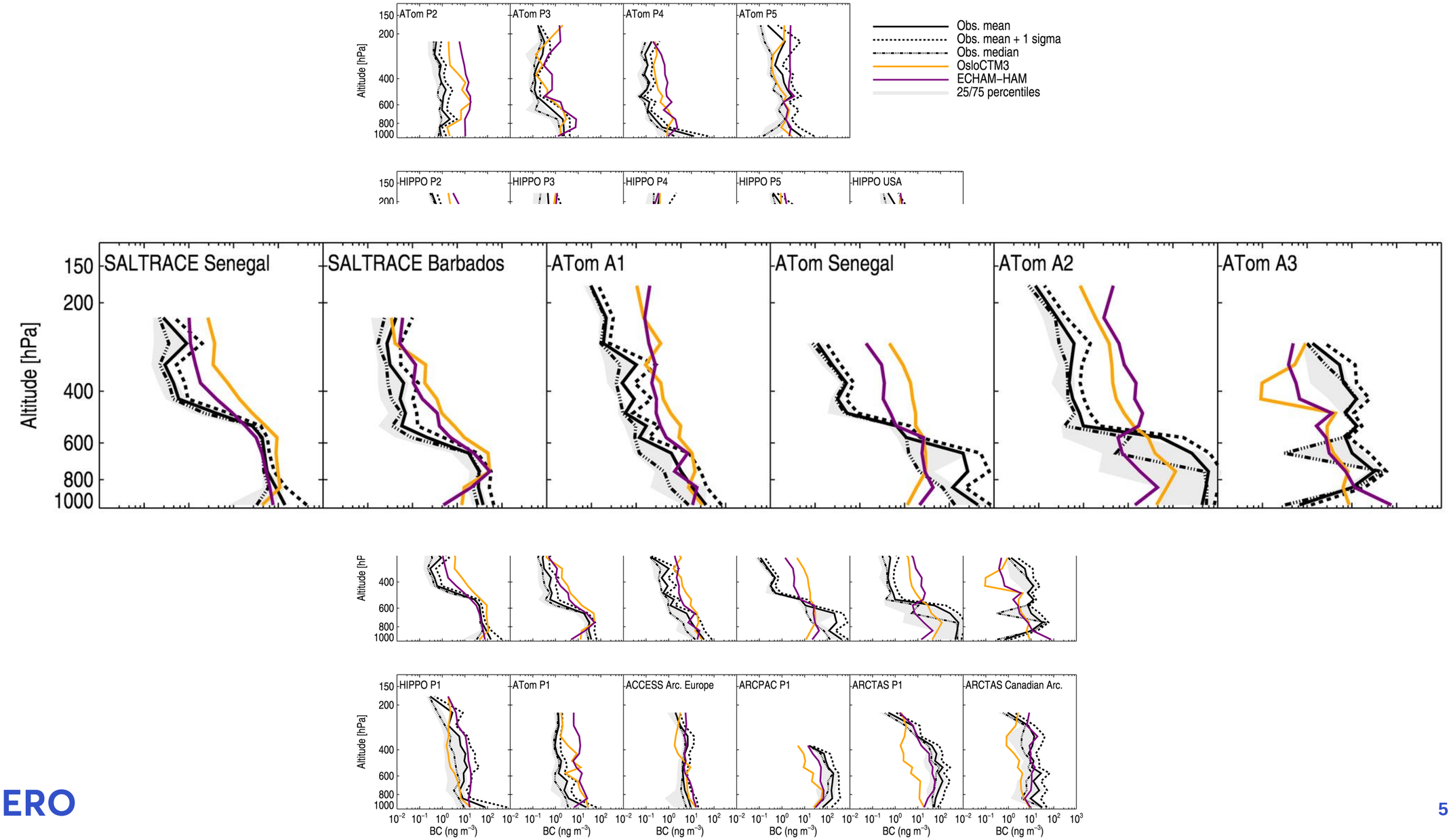
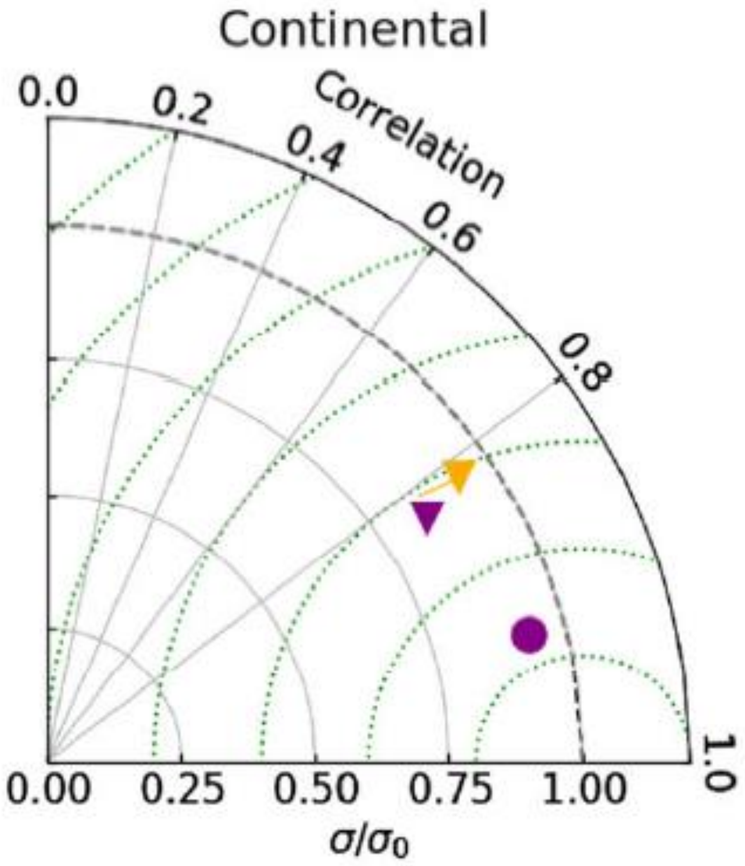
How well does modeled and measured vertical BC distribution agree?

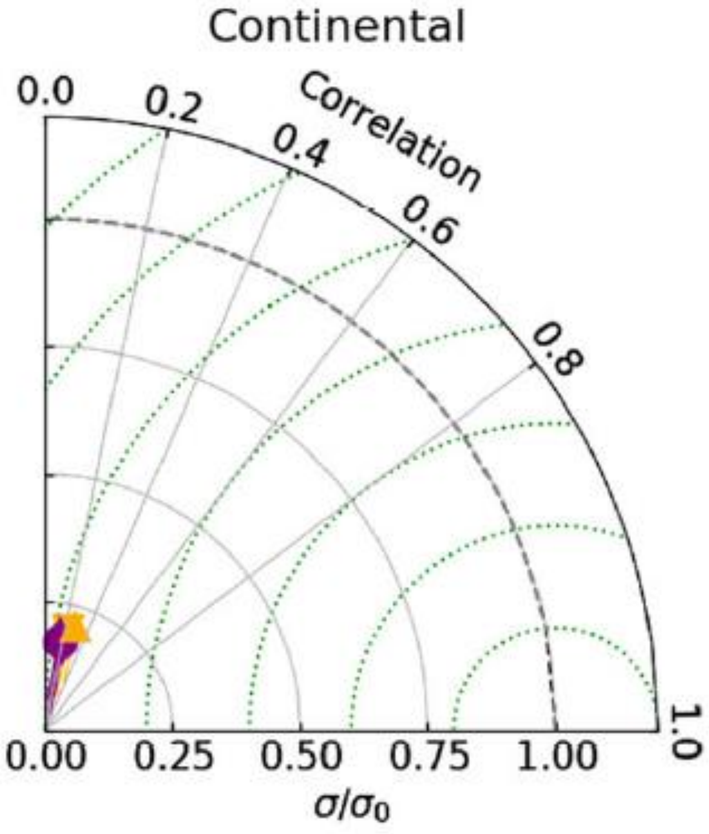


Does sampling methodology influence the model evaluation?

Model data against raw output



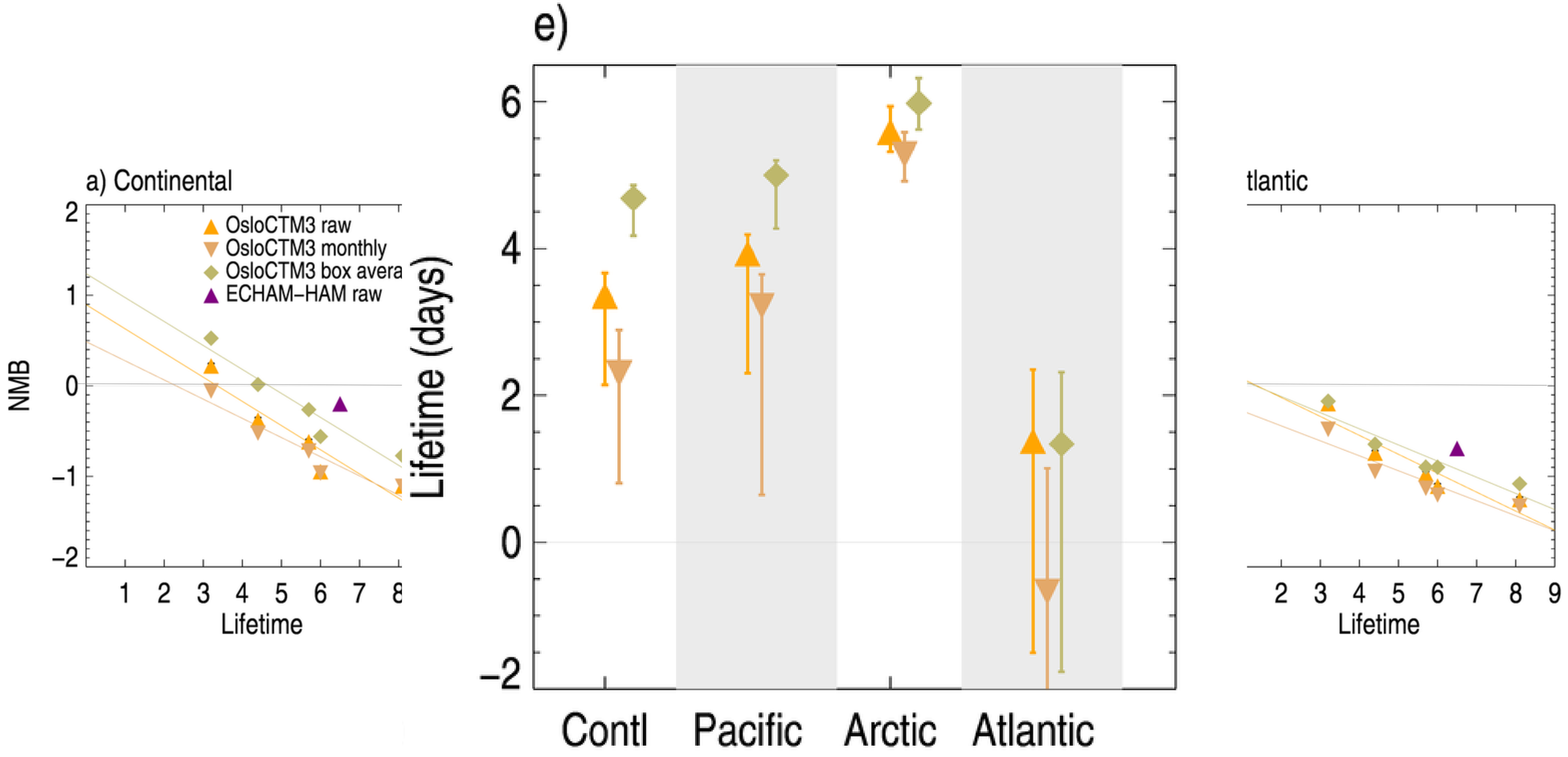
Model data against observations



Sampling coarser model data → lower correlation, reduction in variance.

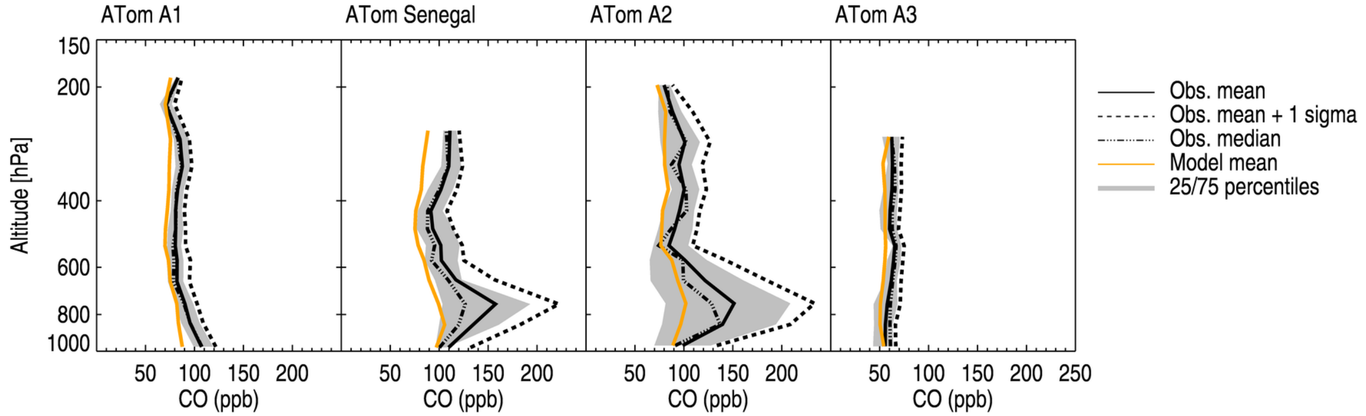
Sampling errors small compared to the model error and inter-model differences.

What is the relationship between global BC lifetime and model skill?

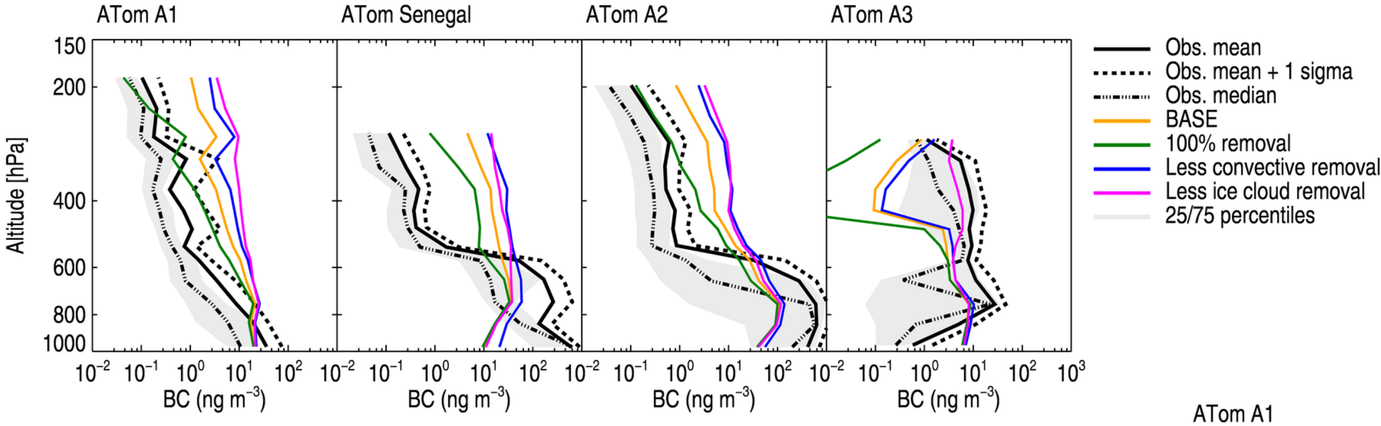


Can we explain the discrepancies in the Atlantic Ocean region?

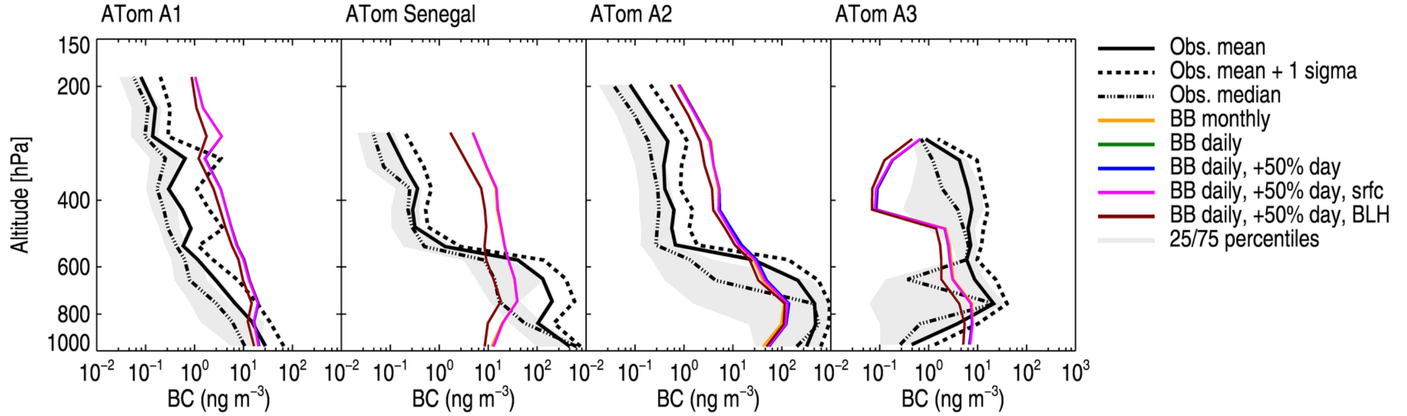
Transport?



Scavenging?



Biomass burning emission injection?



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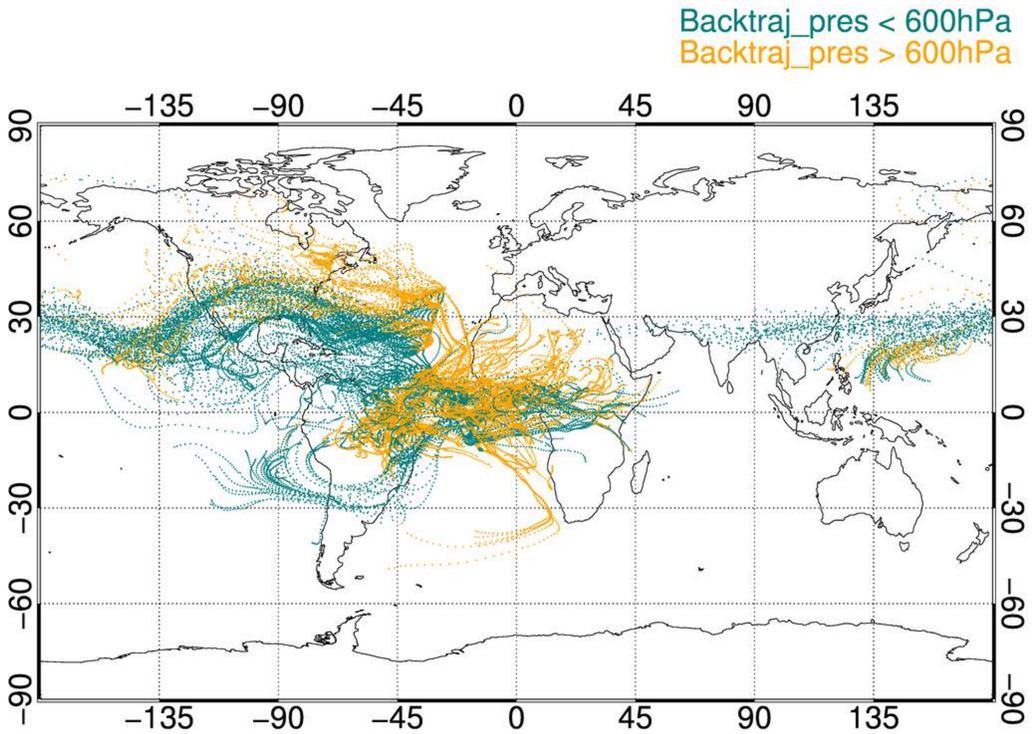
Can we explain the discrepancies in the Atlantic Ocean region?

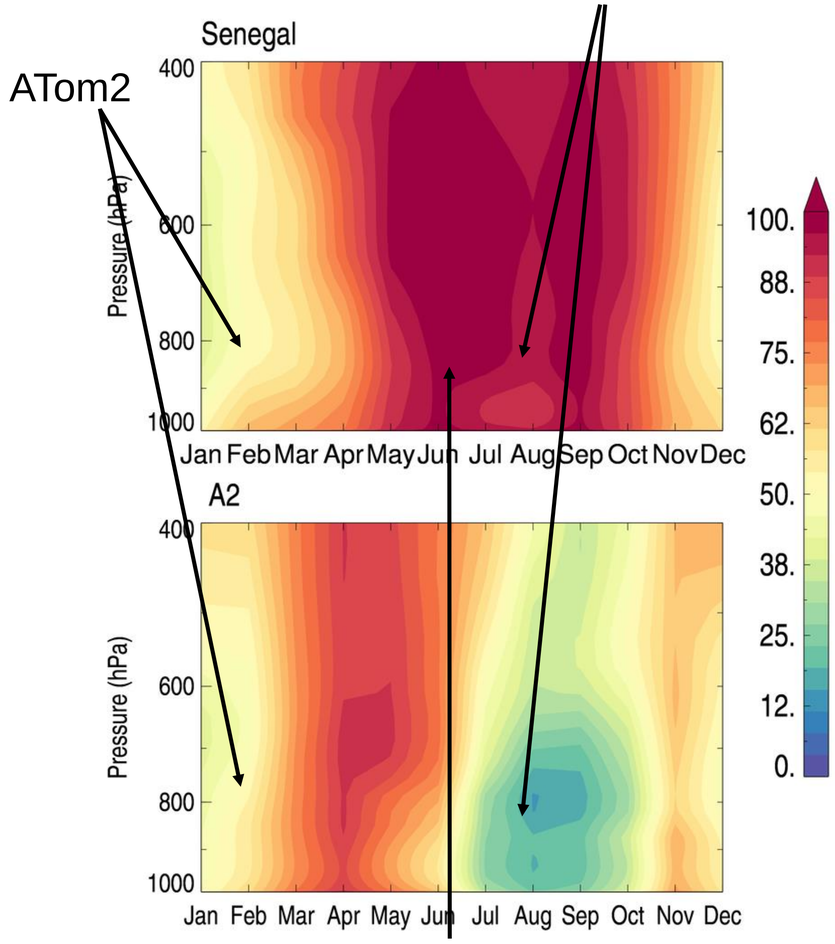
Backtrajectories ATom2 flights over Senegal and A2 regions



Fraction of total BC from fossil fuel and biofuel sources

ATom1

ATom2



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Summary

- Good agreement between modeled BC vertical profiles and aircraft observations for many flight campaigns. Remaining issues:
  - Local biomass burning influence
  - Overstimation of high altitude BC concentrations over Atlantic Ocean
  - Underestimated winter and spring Arctic BC concentrations

- Sampled resolution influences the results, although generally without introducing major bias.

- We confirm a constraint on the global-mean BC lifetime of <5.5 days over a broader geographical range

- But, large regional differences in the diagnosed lifetime, in particular in the Arctic and only a weak constraint in the African outflow region over the Atlantic Ocean

- The concept of a “global-mean BC lifetime” lifetime only as a first order indicator of model skill.