Constraining black carbon emissions from Siberian wildfires using remote sensing aerosol measurements

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Open biomass burning (BB) is a major natural source of absorbing aerosol species (BC and BrC) that affect the Earth's radiation budget. However, BC emission data for remote regions (such as Siberia) have been poorly evaluated against atmospheric observations.

- **Can satellite retrievals of absorption AOD (AAOD) provide useful constraints for BC emissions?**
- **Are the available BC emission estimates for Siberia consistent with satellite observations?**
- **Can sources of BrC from fires be evaluated using the same top-down methods as BC emissions?**

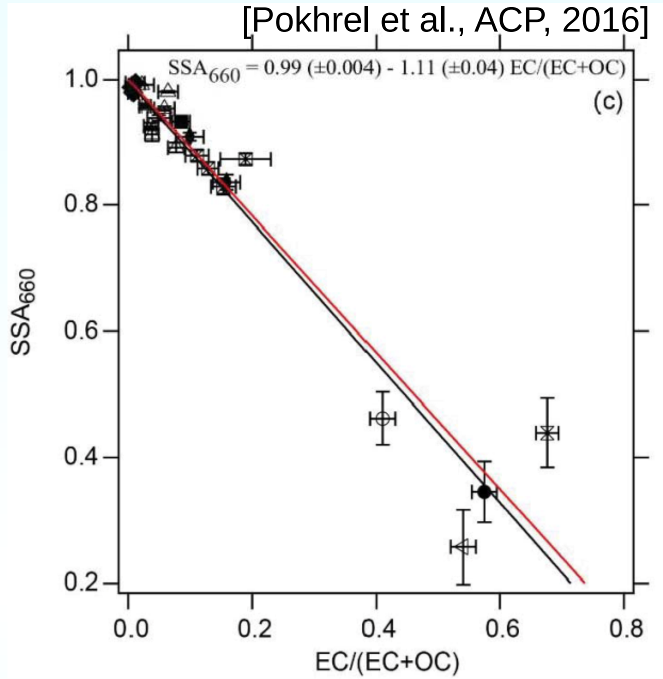
Method: using the AAOD and AOD satellite observations to constrain the EC / OC ratio in BB aerosol

A problem: simulations of AAOD with CTMs are too uncertain

In this study, a robust empirical relationship between EC/(EC+OC) ratio and SSA from the FLAME-4 analysis [Pokhrel et al., ACP, 2016] was used:

$$SSA^{\lambda} \cong a^{\lambda} - b^{\lambda} \frac{[EC]}{[EC]+[OC]} \quad \text{a, b} \approx 1$$

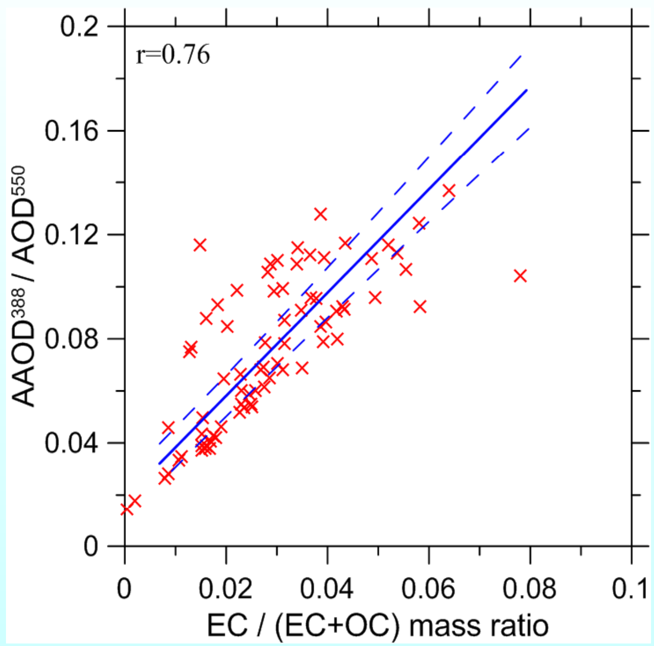
[Pokhrel et al., ACP, 2016]



Analysis of AERONET observations at Siberia [Konovalov et al., 2017]:

- Level 2 SSA , AAOD and AOD data from the Tomsk-22 and Yakutsk sites for summer months of 2012 were considered
- Using simulations with the CHIMERE CTM, we selected the measurements corresponding to dry conditions (RH<60% in BB aerosol columns)

$$\frac{AAOD^{388}}{AOD^{550}} = 1.98(\pm 0.19)\frac{[EC]}{[EC]+[OC]} + 0.018(\pm 0.008)$$



Method: using FRP measurements and model data to constrain BC (EC) emissions

Input data:
- MODIS FRP observations (Level 2 MYD14/MOD14 V6 data product)
- CHIMERE CTM simulations (AOD, BC and OC columns…)
- MODIS AOD at 550nm (Level 2 MYD08/MOD08 V6 data product)
- OMI AAOD at 388 nm (OMAERUV v006 Level 2 data product)

$$E^{s}(t) = \boldsymbol{\Phi}_d \sum_{l} \alpha_l \beta_l^s \rho_l h_l(t)$$

[Konovalov et al., ACP, 2011;2014;2015]

E^s is the emission rate of the species s; Φ_d is the daily mean FRP density; α is the FRP -to- biomass burning rate conversion factor; β_{sl} is the emission factor

Inversion of AOD observations: $\alpha_{opt} = \arg\min[J(AOD_o, AOD_m)]$

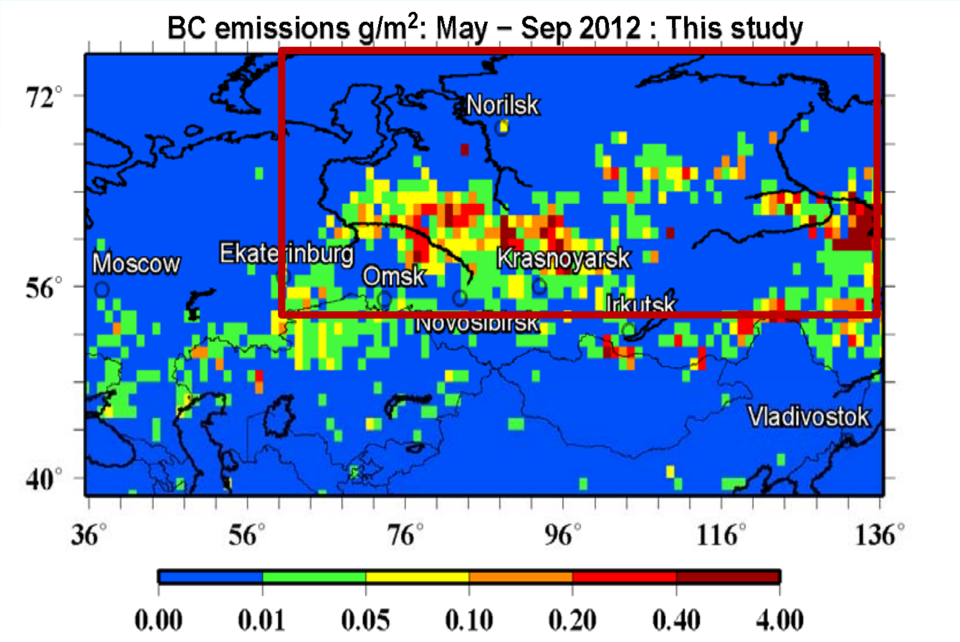
Inversion of AAOD observations: $\beta_{l\,opt}^{EC} = \arg\min[J(AAOD_o, AAOD_m)]$

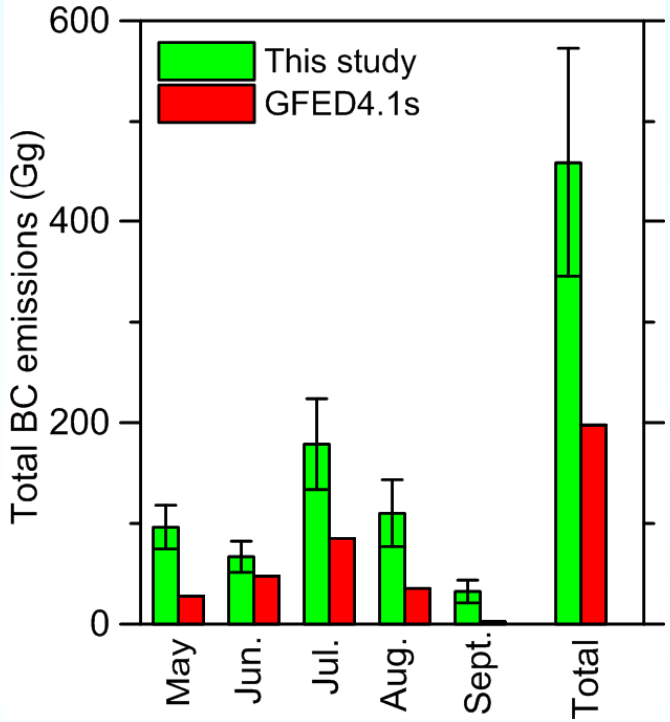
$$AAOD_m^{388} = AOD_m^{550}\left(k_1 \frac{[EC]}{[EC]+[OC]} + k_2\right)$$

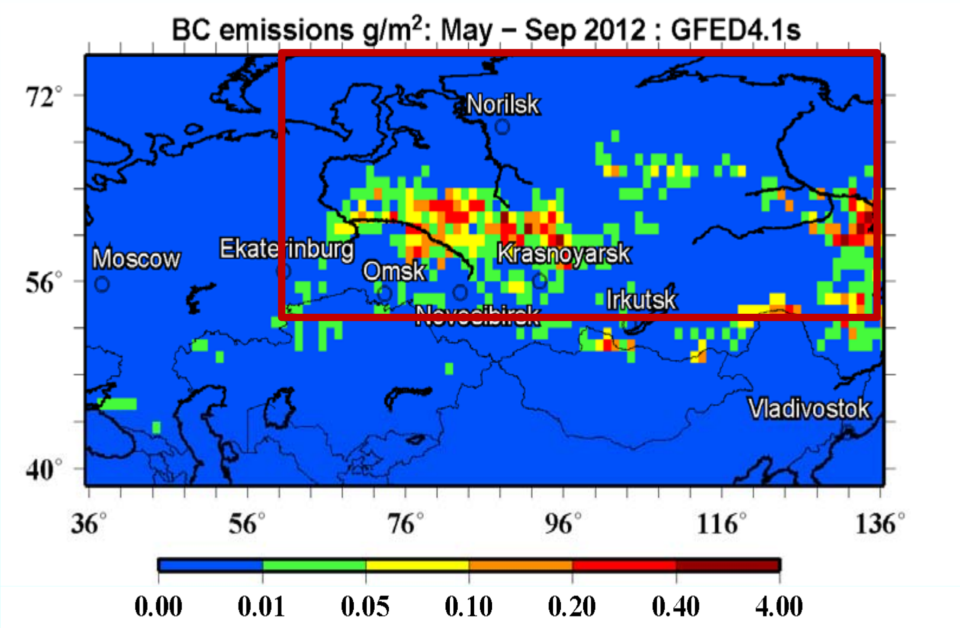
Estimation of uncertainties (bootstrapping)

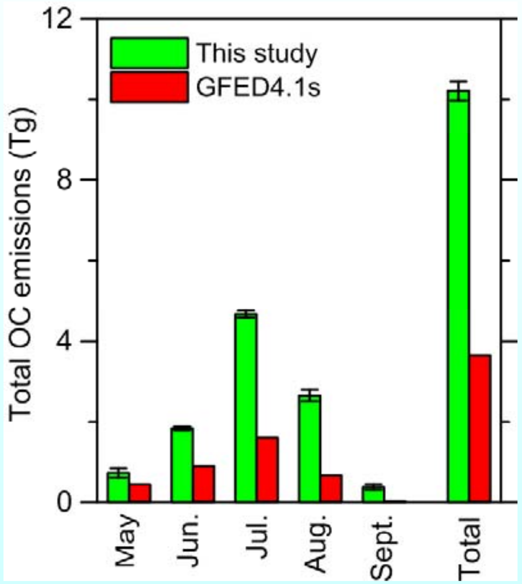
Fires have been aggregated into the two categories: boreal forest fire and other fires (grass, agricultural etc.)

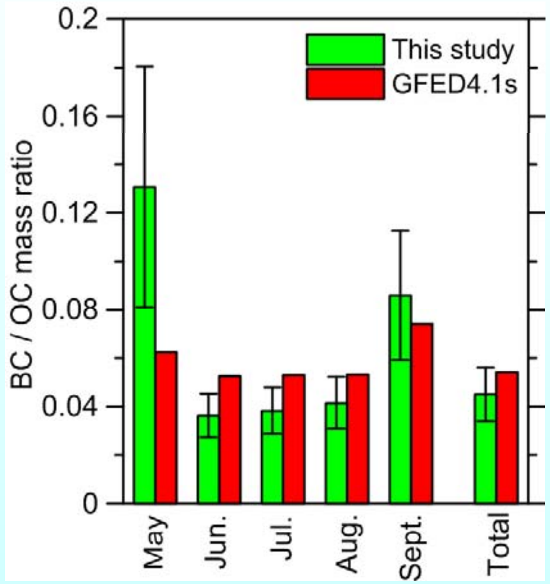
Results: BC and OC emissions in May-Sept. 2012





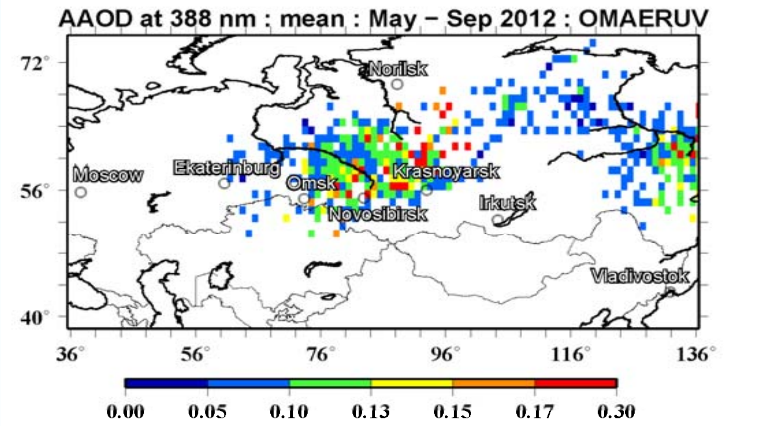


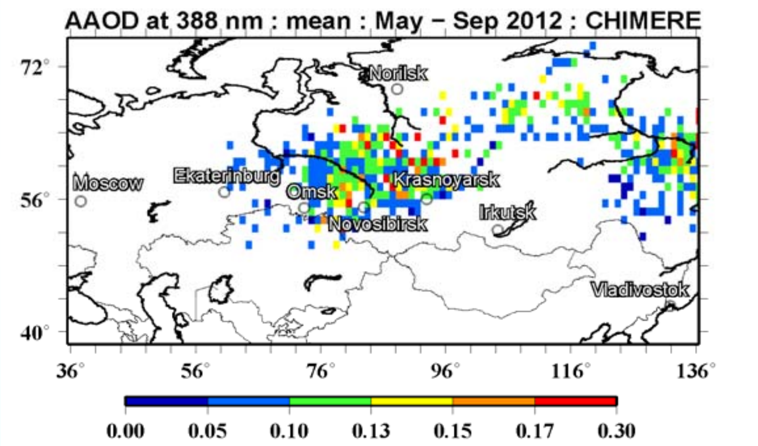


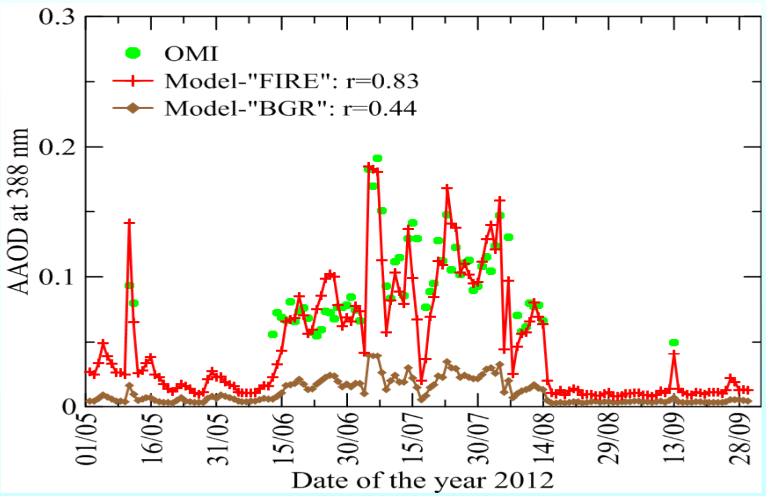


See also: Konovalov et al., ACP, 2014; 2015; 2017

Results: Validation and effects of BB aerosol aging







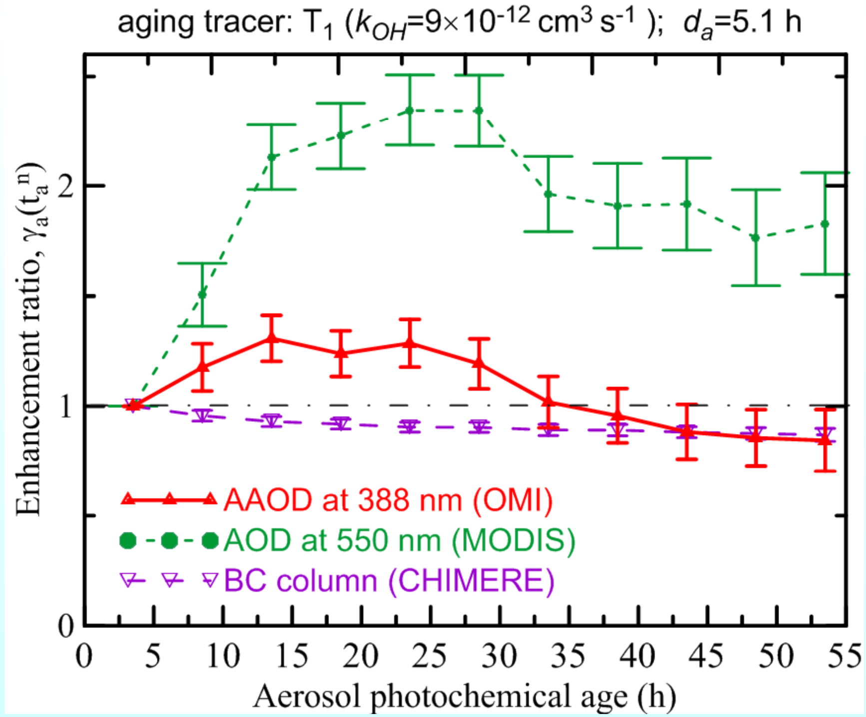
The Enhancement Ratio (γ_a) for AAOD:

$$\gamma_a(t_a) = \frac{\tau(t_a) - \tau_b(t_a)}{\tau_t(t_a)}$$

$$\gamma_a(t_a^n) = \arg\min \sum_{i,j \in \Lambda n} \left(\tau_o^{ij} - \tau_m^{ij}\right)^2,$$

$$n \in [1, N_a]$$

- τ : ***AAOD observations***
- τ_b : *background (modeled) AAOD*
- τ_t : *AAOD of a modeled aerosol tracer (no aging, no deposition)*
- t_a : ***BB aerosol photochemical age***



See also : Konovalov et al., ACP, 2017

Perspectives

- The current estimates of the BB impact on the radiation balance in the Northern Eurasia and in the Arctic may need to be revised
- A consistent representation of emissions, optical properties and atmospheric evolution of BB aerosol in models

References

Konovalov, I.B., Beekmann, M., Berezin, E.V., Formenti, P., Andreae, M.O. Probing into the aging dynamics of biomass burning aerosol by using satellite measurements of aerosol optical depth and carbon monoxide. *Atmos. Chem. Phys.* 2017, *17*, 4513–4537.

Konovalov I.B., Lvova D.A., Beekmann M., Estimation of the elemental to organic carbon ratio in biomass burning aerosol using AERONET retrievals. *Atmosphere*. 2017, 8, 122.

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This study was supported by the Russian Science Foundation (grant No. 15-17-10024)