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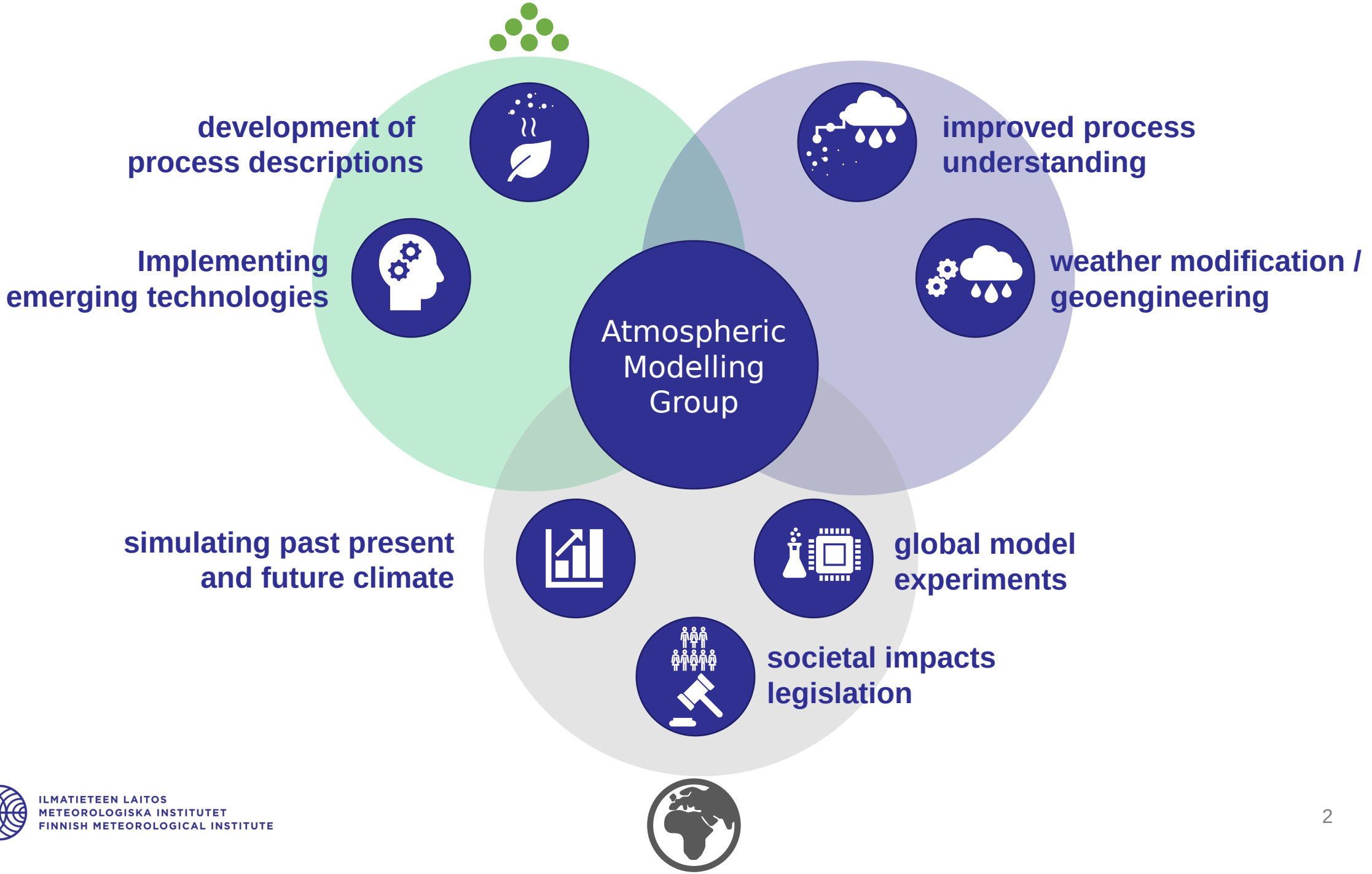
How does the composition of small-scale combustion emissions affect their climate effects?

Harri Kokkola


development of
process descriptions
improved process
understanding
Implementing
emerging technologies
weather modification /
geoengineering
Atmospheric
Modelling
Group
simulating past present
and future climate
global model
experiments
societal impacts
legislation

Climate effects of small scale combustion

- gaseous emissions (greenhouse gases, semivolatile compounds)
- particulate emissions
- **”BC is the SLCF of highest priority in the Arctic, due to its warming effect when the dark particulate matter is deposited on snow and ice and speeds the rate of warming.”**

ACAP, 2014, Reduction of Black Carbon Emissions from Residential Wood Combustion in the Arctic – Black Carbon Inventory, Abatement Instruments and Measures. Arctic Contaminants Action Program (ACAP)

- **Contribution of BC from residential combustion underestimated**

Stohl et al., 2013

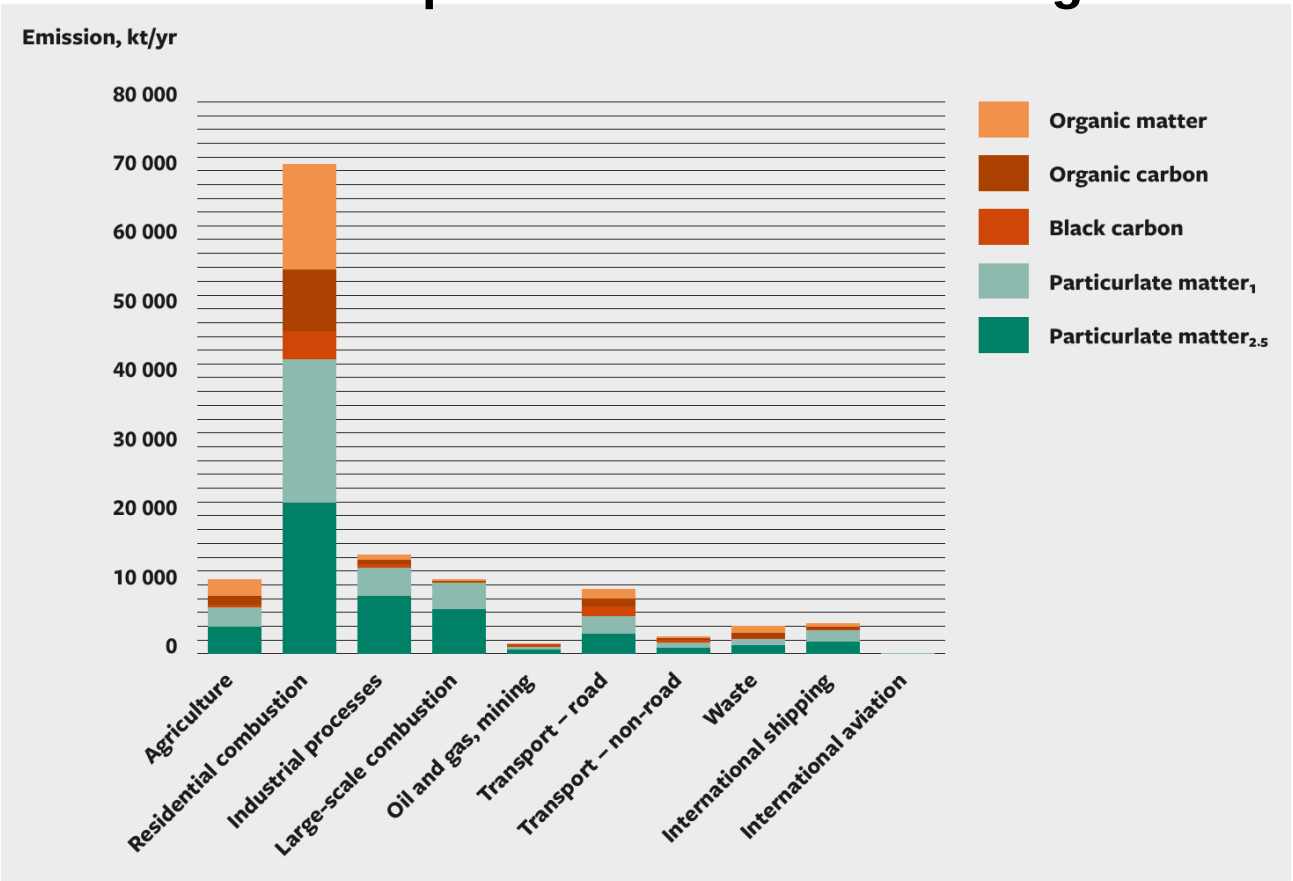
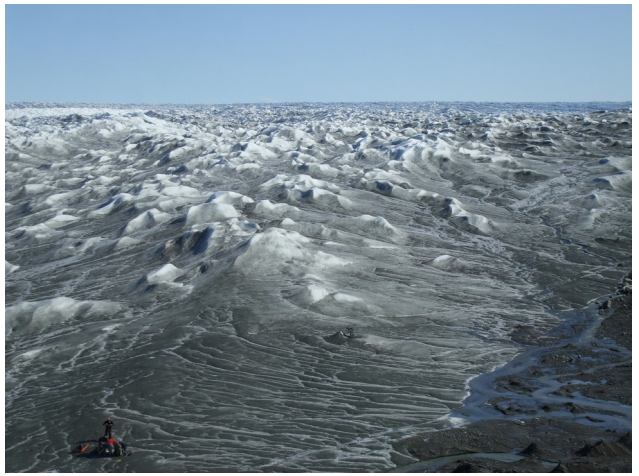
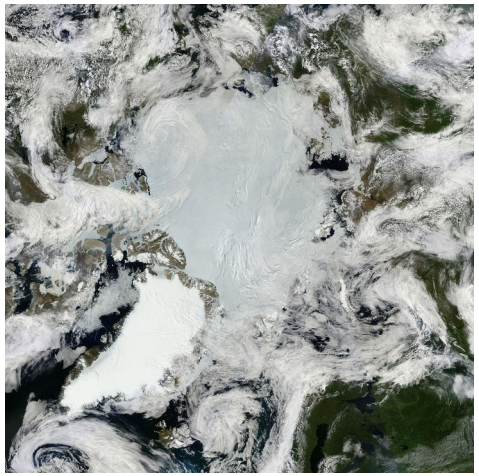


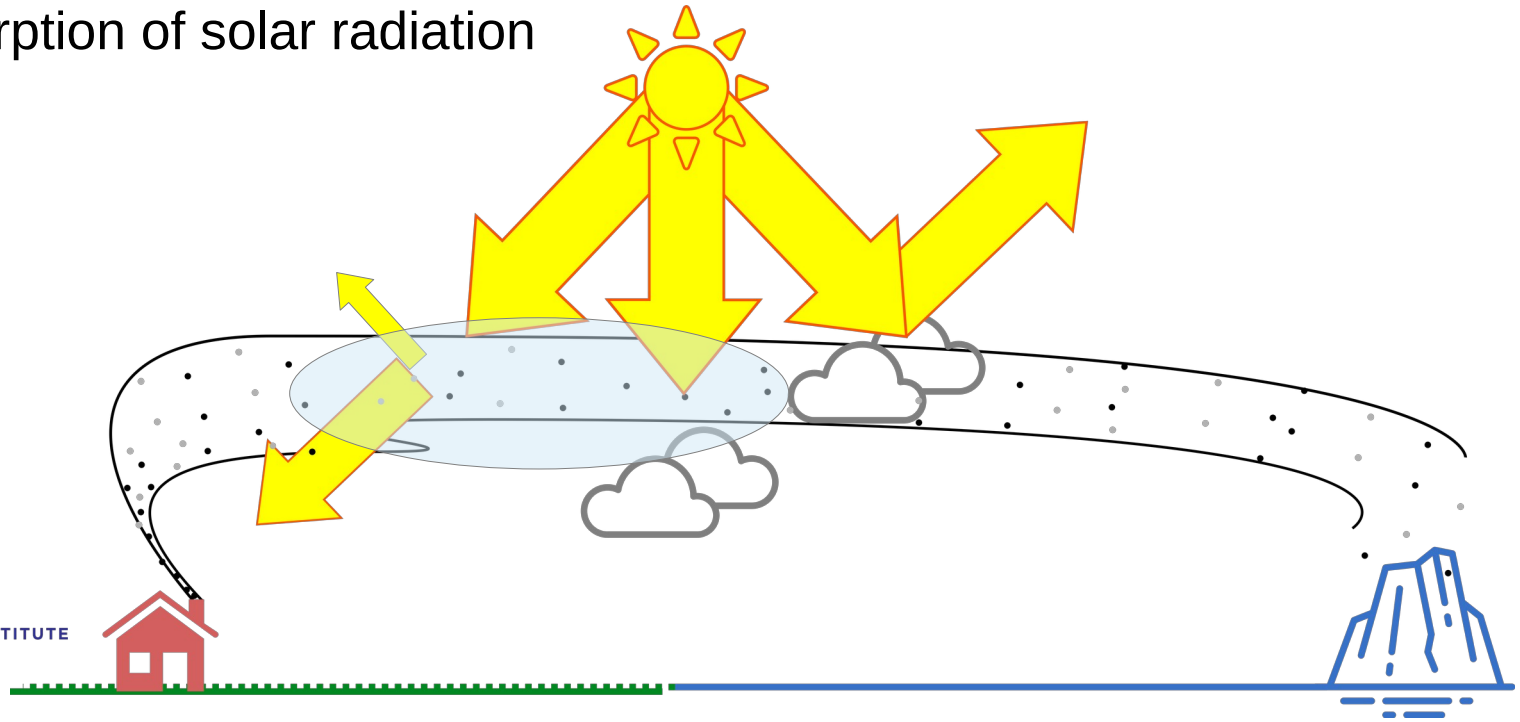
Figure 1: The figure shows sectoral emissions of particulate matter in 2010 (kton per year) and is adapted from Klimont et al. (2017).[5] Data originates from ECLIPSE V5a

Climate effects of small scale combustion



Aerosol-radiation interactions
- scattering and absorption of solar radiation



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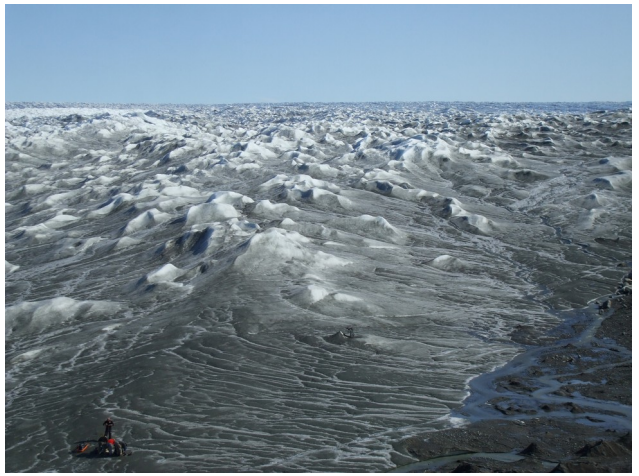
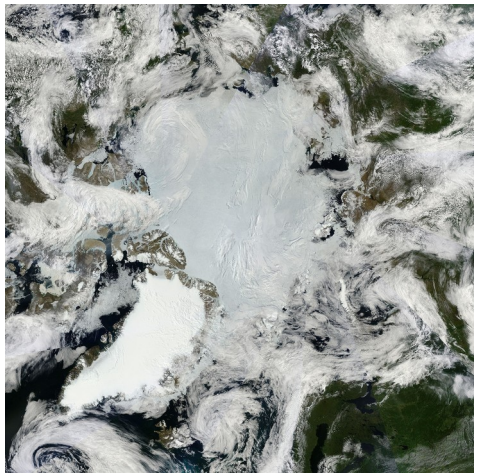
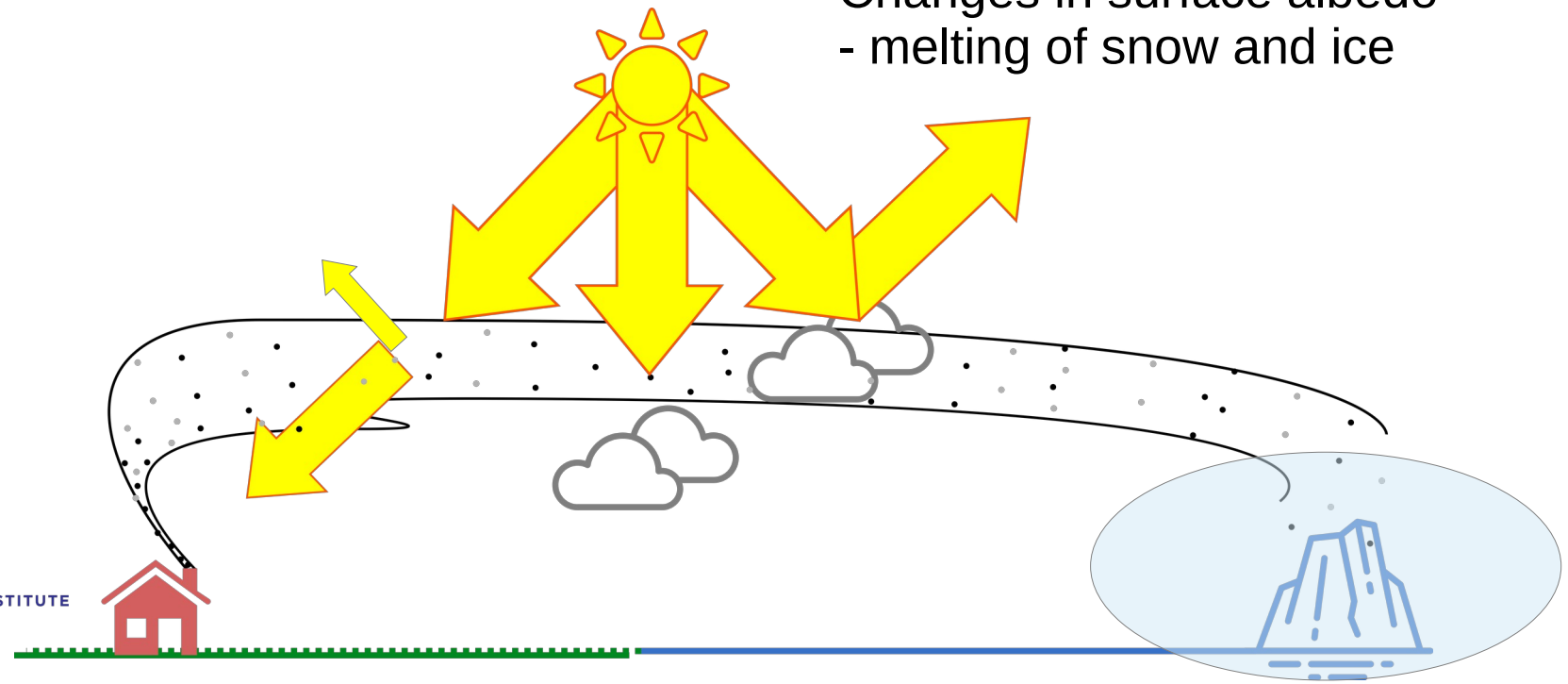
Climate effects of small scale combustion



Changes in surface albedo
- melting of snow and ice



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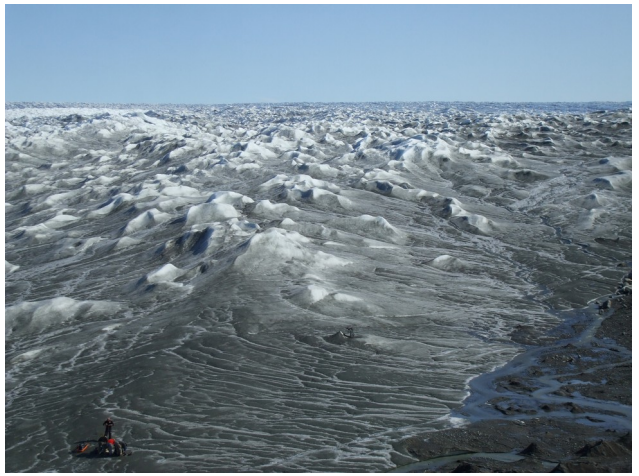
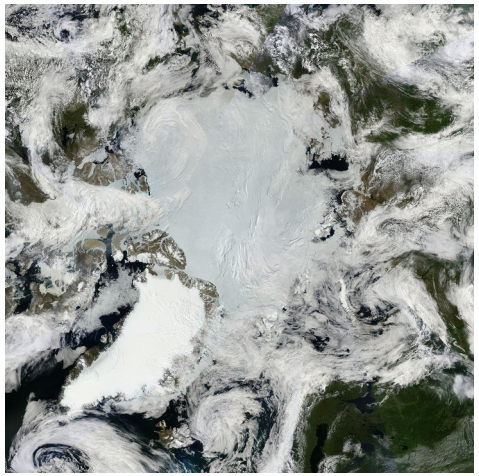
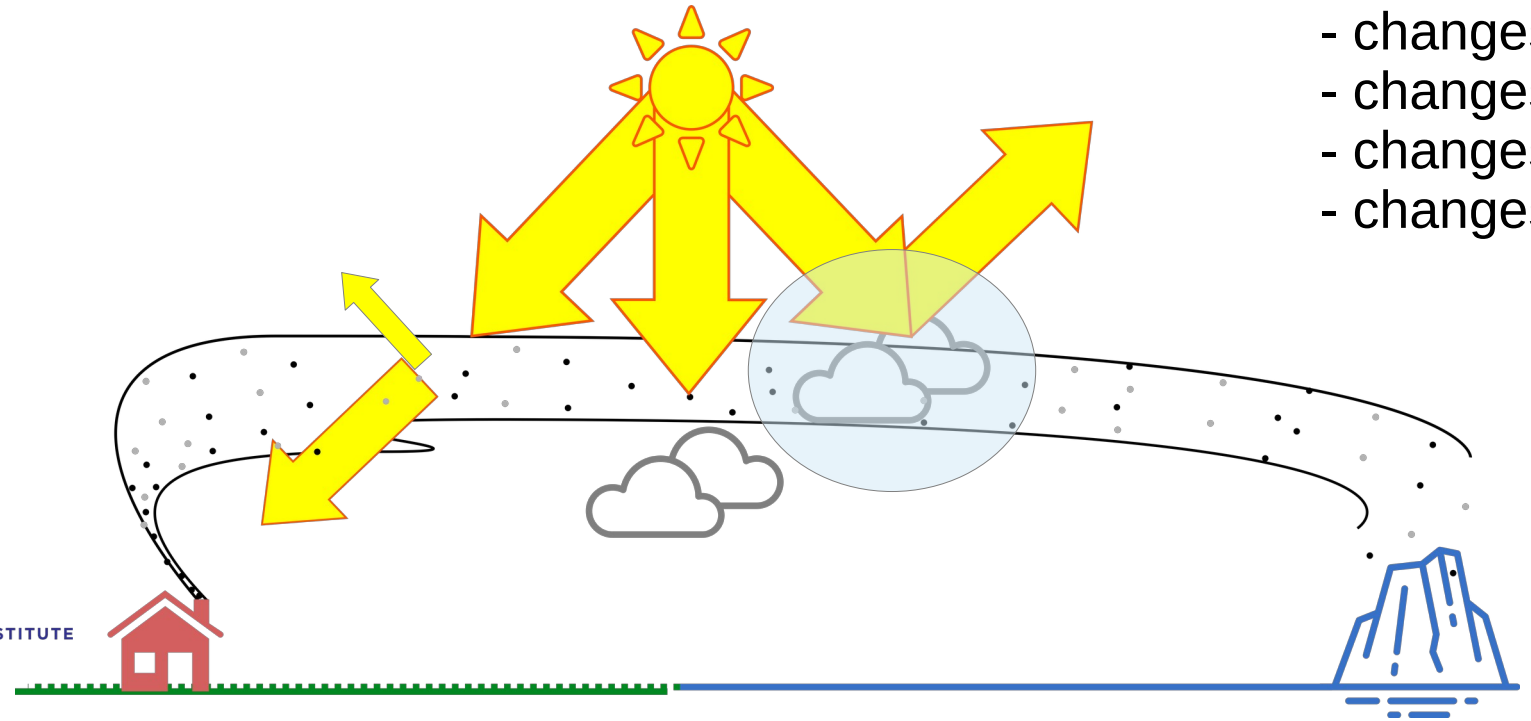
Climate effects of small scale combustion



Aerosol-cloud interactions
- changes in cloud properties
- changes in cloud reflectivity
- changes in cloud cover
- changes in precipitation



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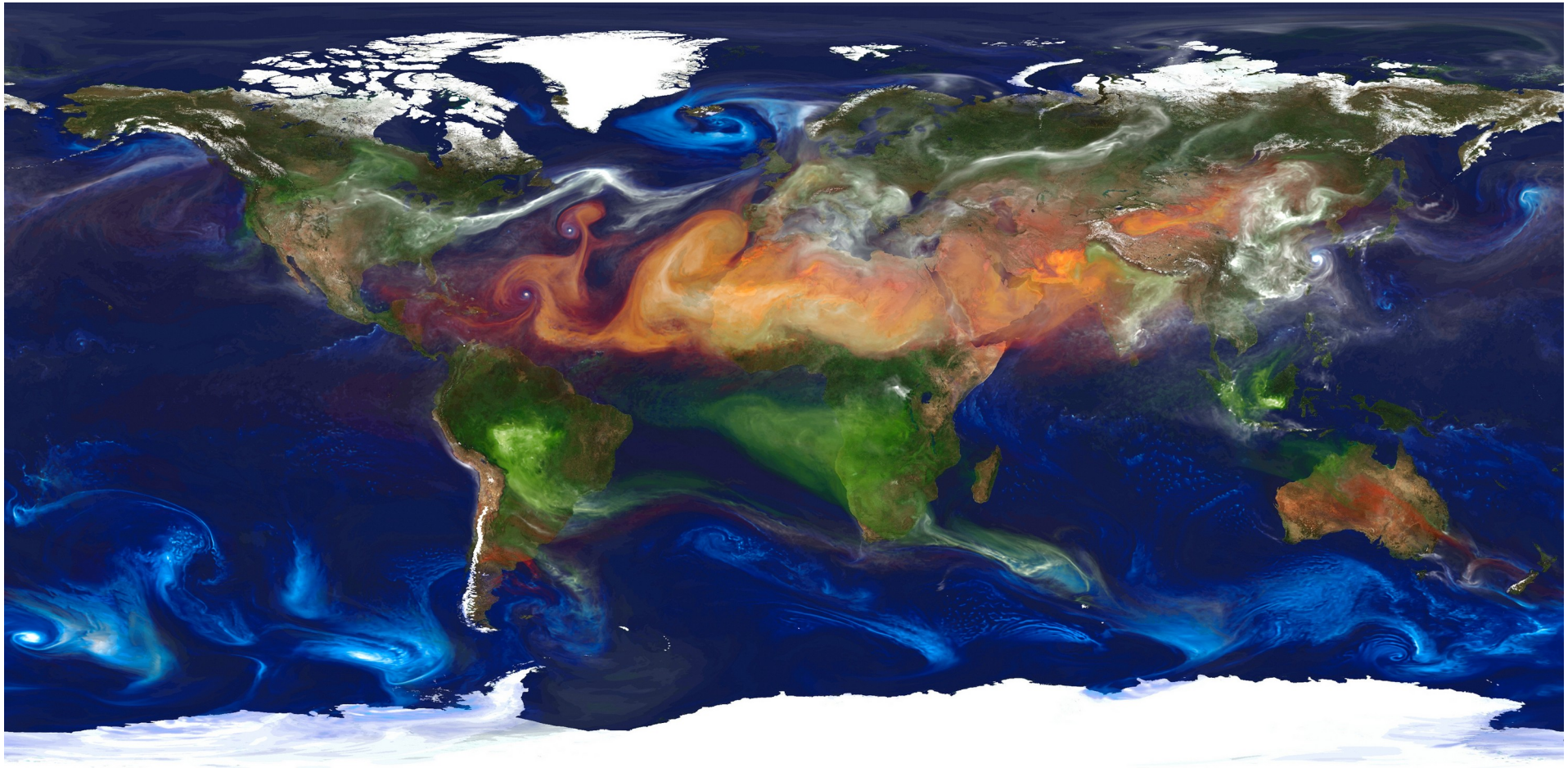
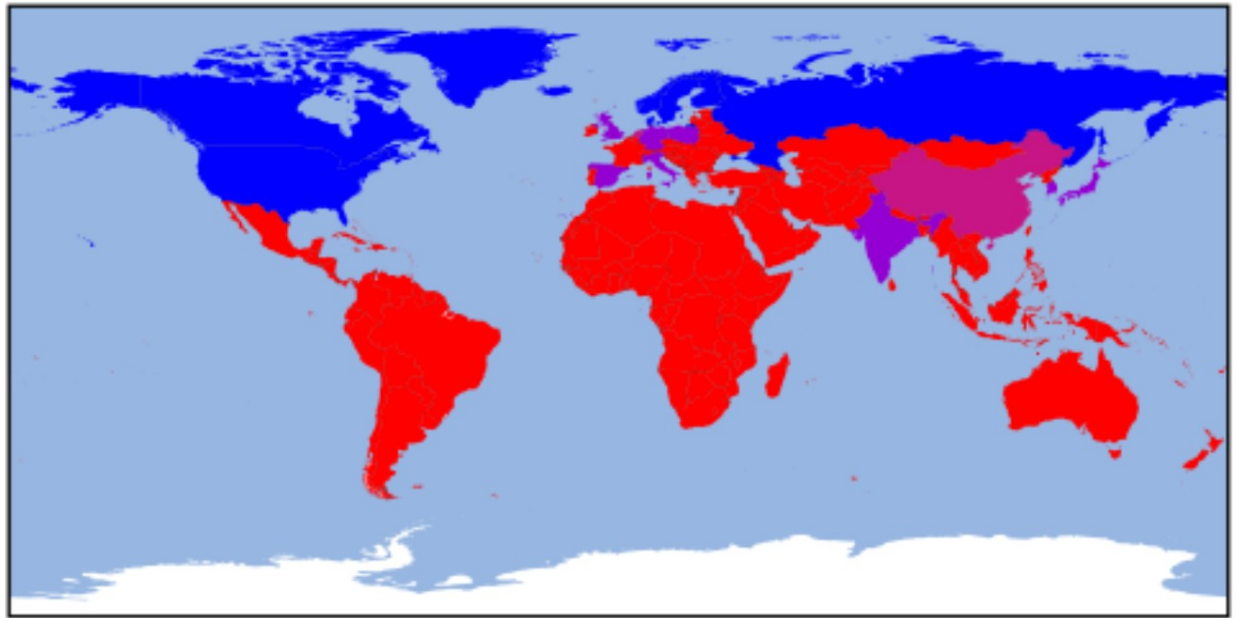
Climate effects of small-scale combustion

- Studying the climate effects with global climate models

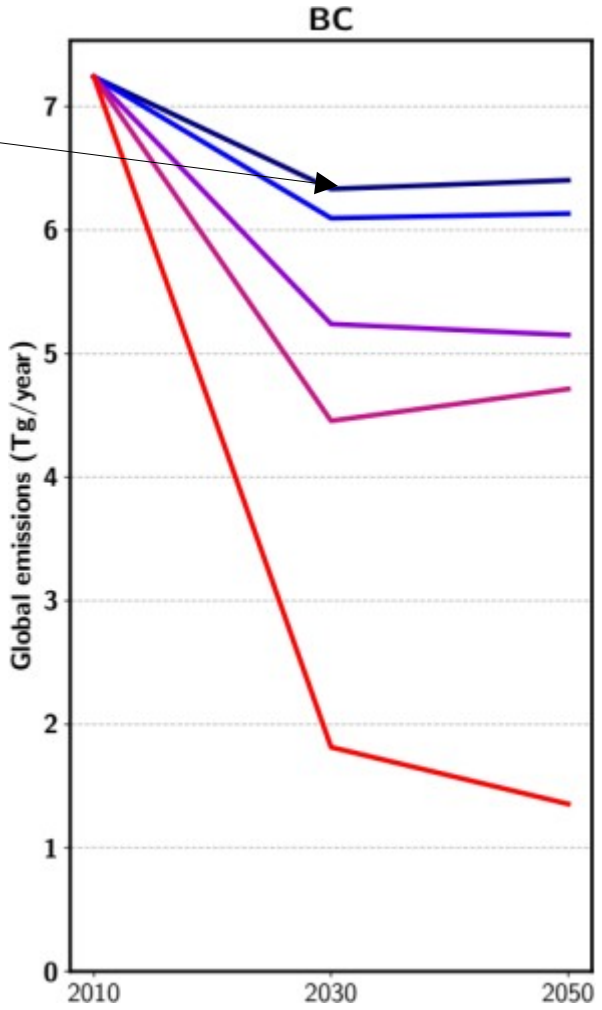


Climate effects of small-scale combustion

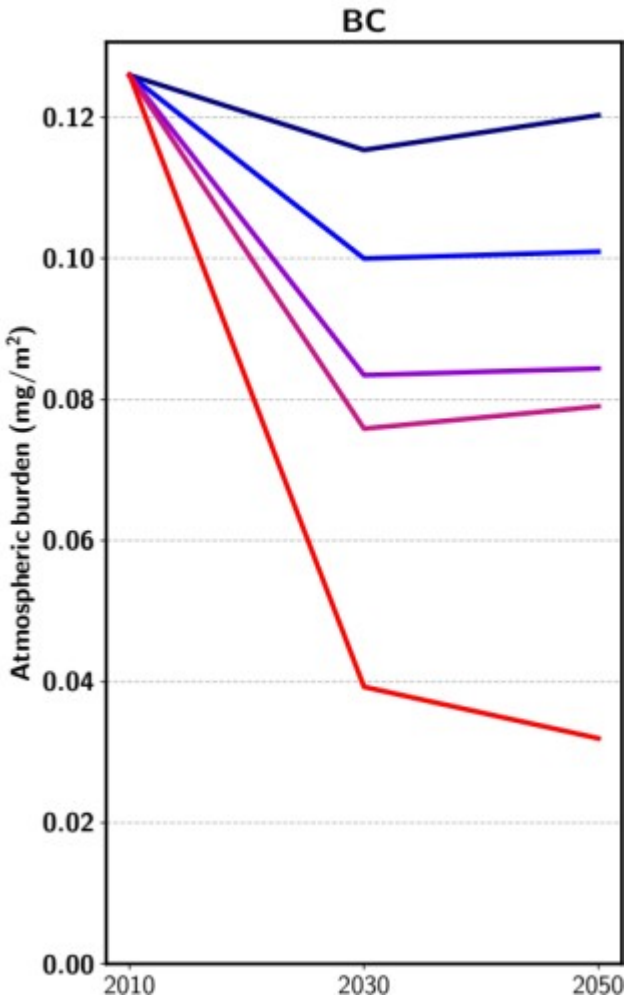
- Arctic is sensitive to absorbing aerosol
- How do emission translate to changes compare to **current legislation**



Black Carbon emissions



Black Carbon burden



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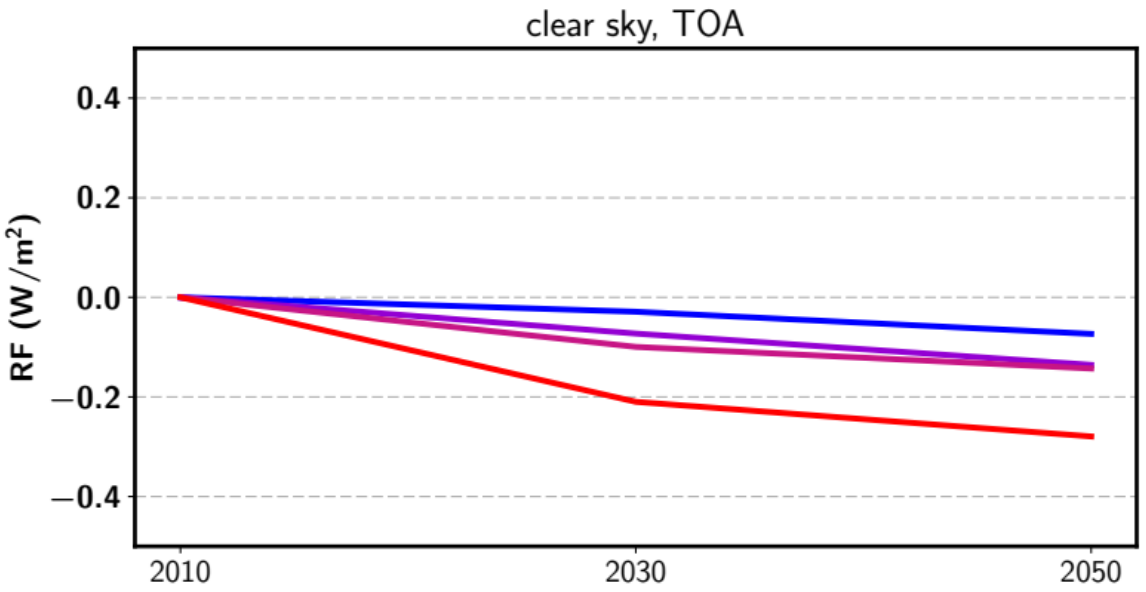
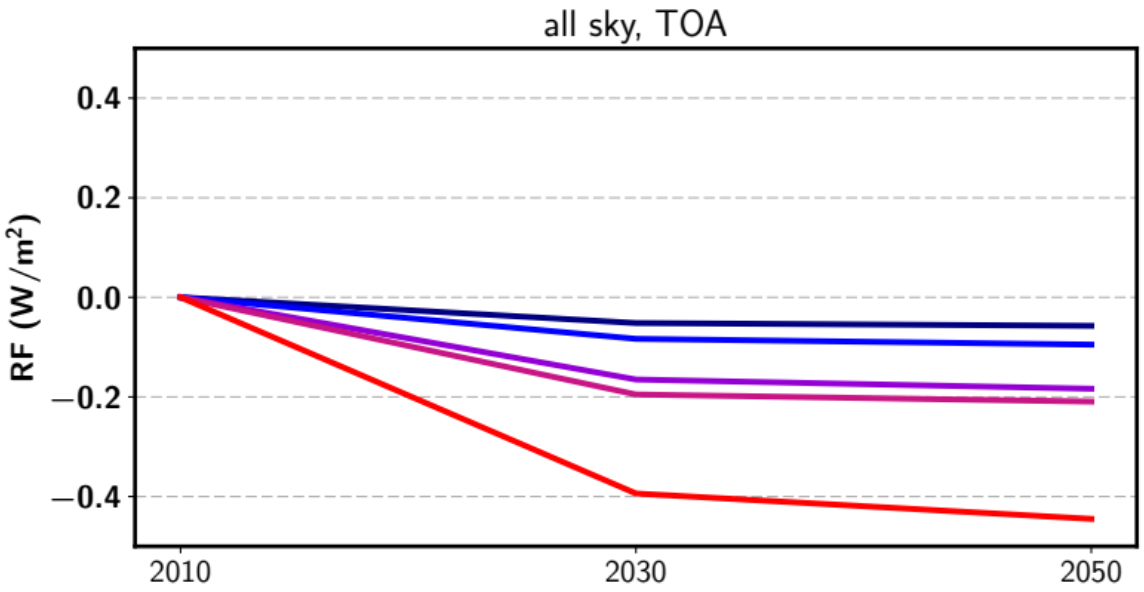
Kühn et al. 2020. Effects of black carbon mitigation on Arctic climate. Atmos. Chem. Phys., 20, 5527–5546, https://doi.org/10.5194/acp-20-5527-2020

Aerosol-radiation effects over the Arctic

- Radiative forcing due to aerosol-radiation interactions is clear
- Reductions lead to negative forcing

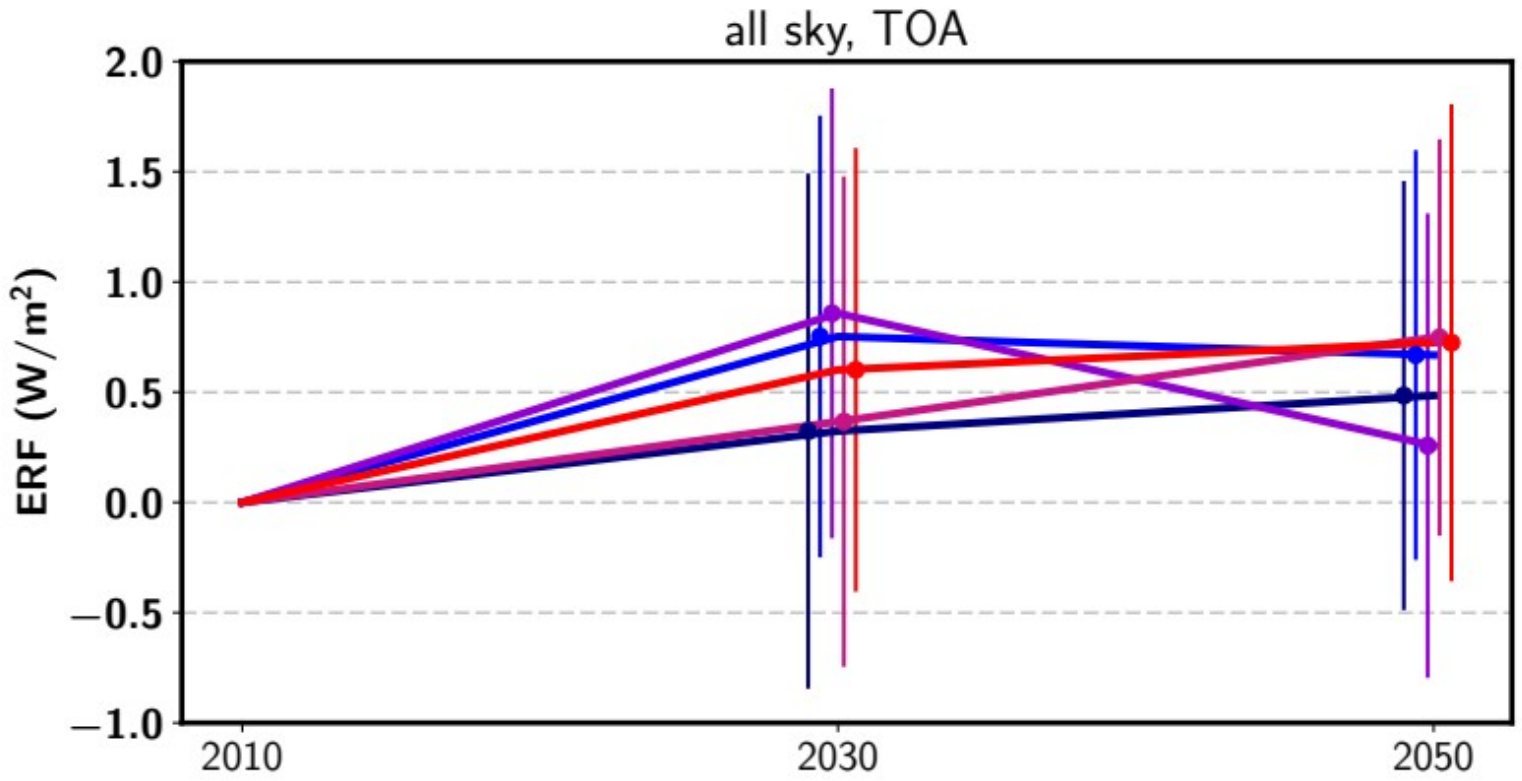




Aerosol-cloud interactions effects over the Arctic

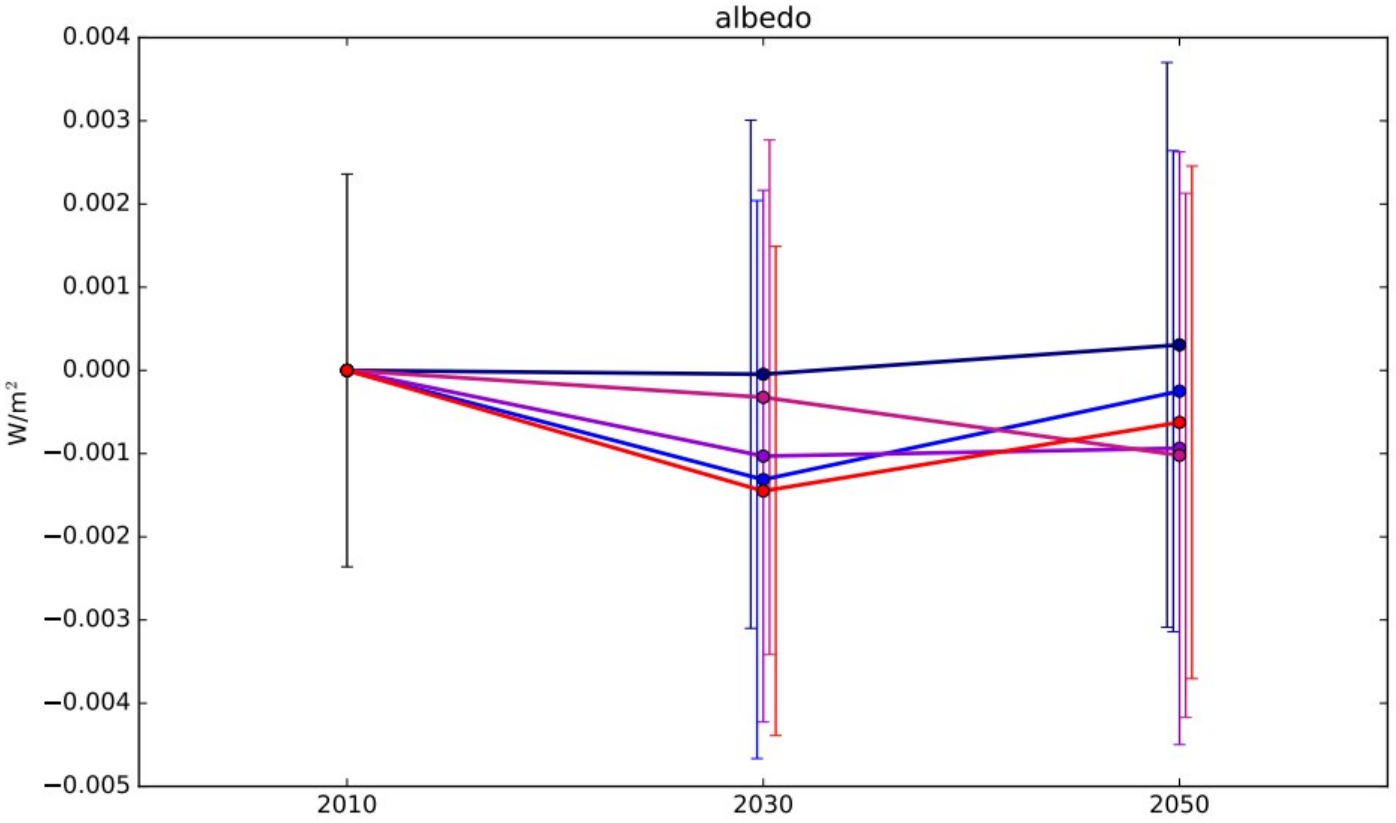
Aerosol-cloud interactions effects over the Arctic

- Radiative forcing due to aerosol-cloud interactions uncertain, possibly positive in sign
- Model dependent



Albedo effects over the Arctic

- Modification of surface albedo by aerosol is also very uncertain

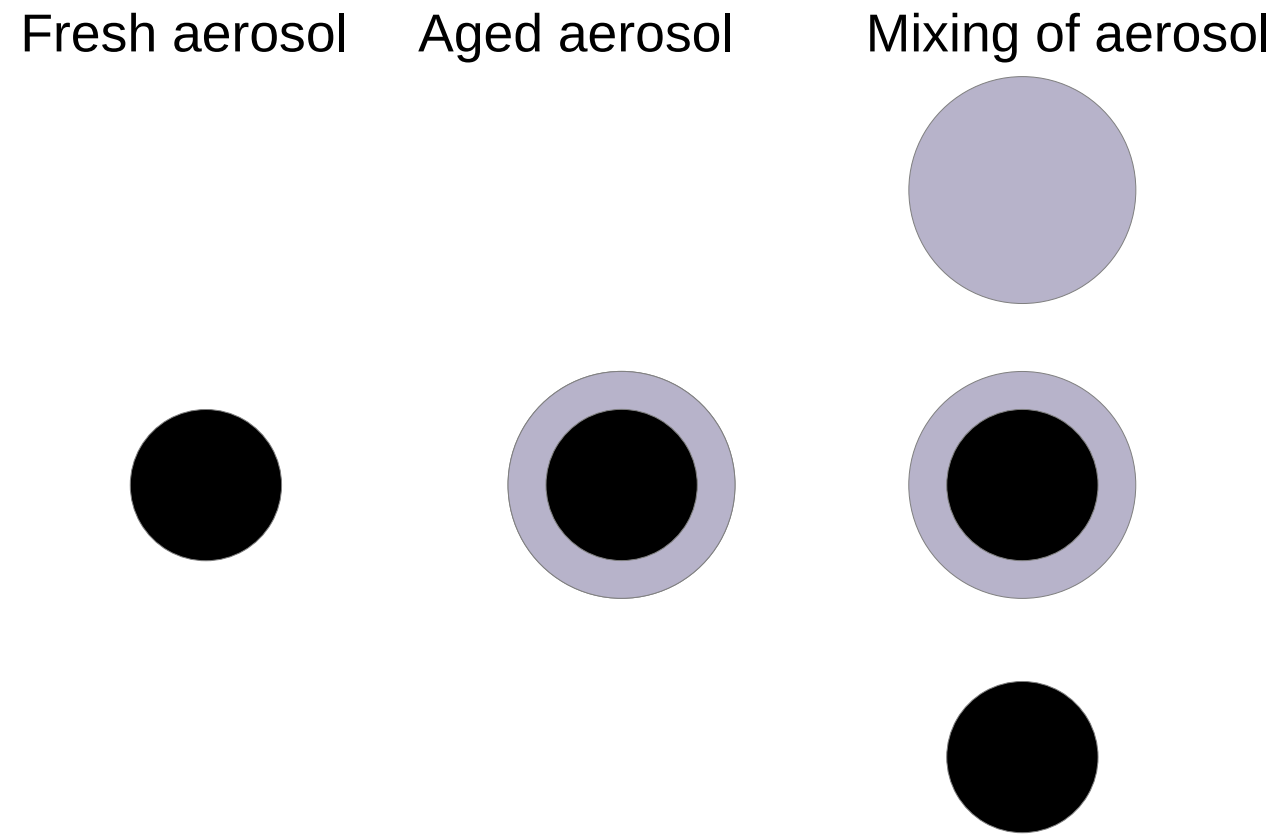


Climate effects of small-scale combustion

- Emitted aerosol lifetime short (days)
- Climate effects sensitive to:
    - composition
    - size distribution
    - optical properties

- Aerosol aged by semivolatiles, chemical processing

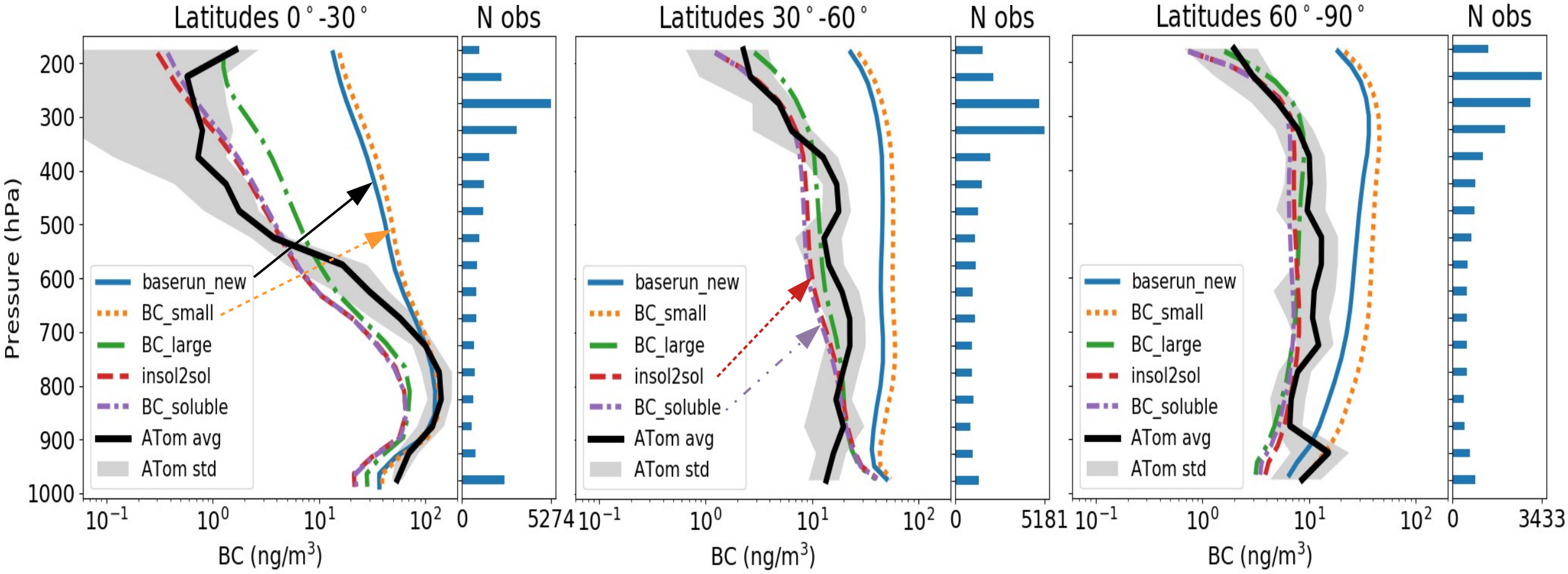
- Chemical aging affects the optical properties



Vertical profiles from NASA ATOM campaing

Near the sources

Arctic region



Assumptions on aerosol properties have strong implications on aerosol transport
- BC lifetime varies between **5 to 15** days depending on the assumptions

Conclusions

- Aerosol-cloud interactions remains the largest challenge in estimating climate effects
- Need better knowledge on:
  - How aging changes the cloud activity of particulate matter
  - Hygroscopicity
  - Level of mixing of different aerosol compounds
  - Optical properties
  - Climate model friendly parameterizations

”After decades of research, the importance of black carbon (BC) as an INP remains unresolved” Schill et al., (2020)

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Thank you!