Study of black carbon deposition on Arctic snow and ice and its impact on climate change

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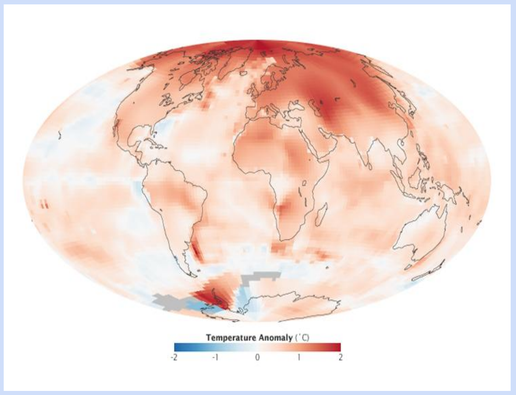
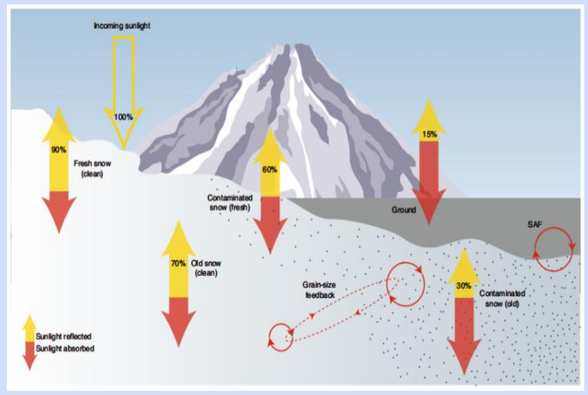
Introduction

- The rapid warming of the Arctic, accompanied by glacier and sea ice melt, has significant consequences for the Earth's climate, ecosystems, and economy.
- Atmospheric energy is an essential property of atmosphere and snow albedo is important in determining the surface energy budget of polar regions.
- The deposition of BC could greatly affect rapid warming in the Arctic by triggering the snow albedo feedback.



Rapid Arctic warming



How the deposition of BC impacts snow albedo and net solar radiation△

Models

BC deposition

Run PWRF with reanalysis data → Obtain the input parameters of SNICAR → Calculate snow albedo with BC → Evaluate the radiative forcing by BC deposition → Energy budget calculations

netRad=SH+LH+G+PH

$netRad=LW_{net}+SW_{net}$

$RF=Rad\downarrow\times(\alpha_{clean}-\alpha_{BC})$

Offline simulations of PWRF and SNICAR

Sensitivity Studies

SNICAR in PWRF → PWRF/Noah-MP → Impacts of BC deposition on Arctic climate change

SNICAR parameters provided by PWRF:
solar zenith angle , snowpack density, snowpack thickness, Background albedo

Case Study
Mechanism analysis

Set snow grain effective radius = 150μm

All BC in snow and ice is uncoated

Fully coupled SNICAR in PWRF

Experiments and Data

Type	Name	BC deposition
Offline	Off_Sen0	5-20ng/g^{-1}
Coupled	Sen1	As observed value
Coupled	Sen2	As 10 times as Sen1

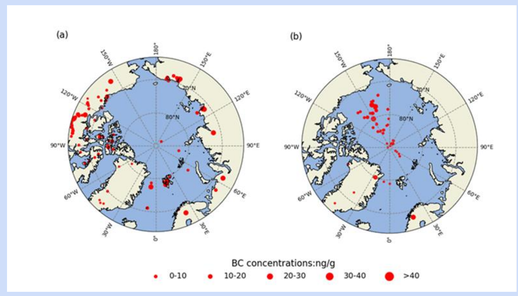
Experimental Designs

Main Physics	Schemes
Microphysics	Purdue Lin
Radiation	RRTM
Surface layer	M-O (Janjic Eta) scheme
Land surface	Noah-MP
Boundary layer	MYNN
Cumulus	Kain-Fritsch

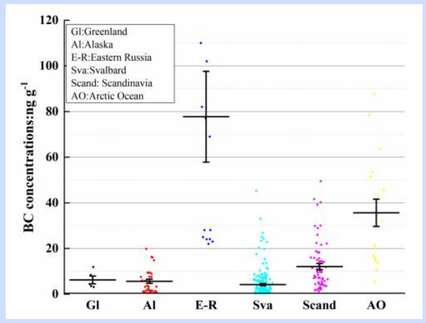
Period: 2019.4.13-2019.4.21, Resolution: 27Km， Layers in vertical: 45
Grid points in x and y coordinate system: 220×220
Data:ERA5 reanalysis dataset; AMSR2 seaice; NCEP-FNL snow

Parameters Used in the Numerical Experiments

Measurements of BC in snow and ice

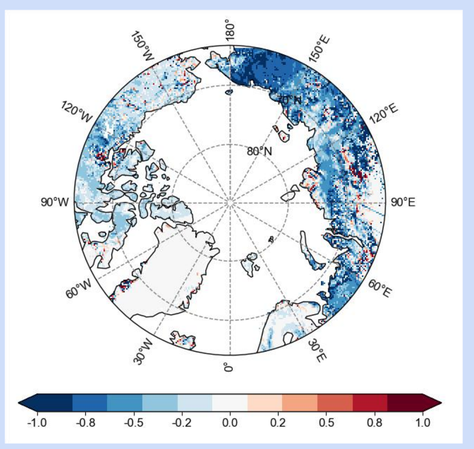


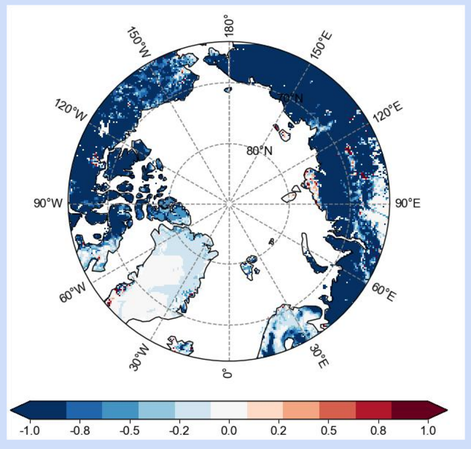
Locations and concentrations of BC snow observations collected from Arctic campaigns between 2005–2010 in spring (a) and summer (b).

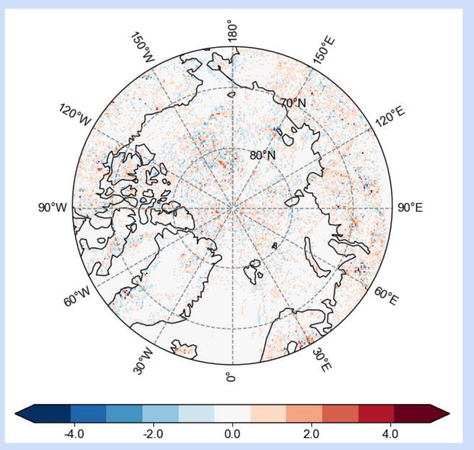


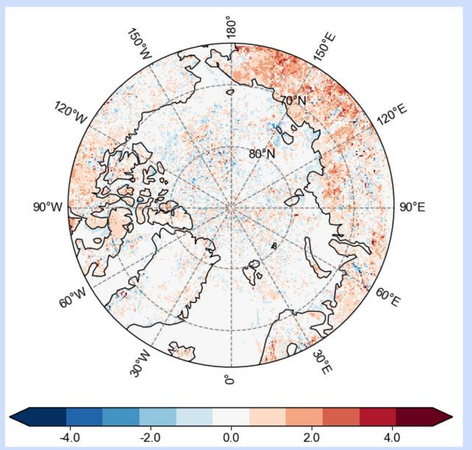
Variations in BC concentrations in snow across different Arctic regions.

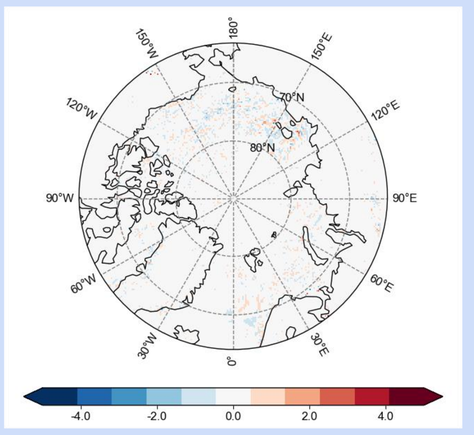
Sensitivity Studies

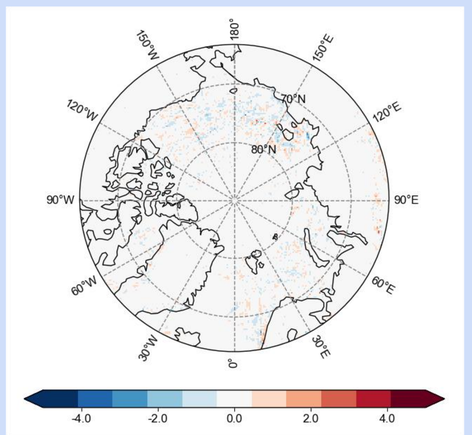






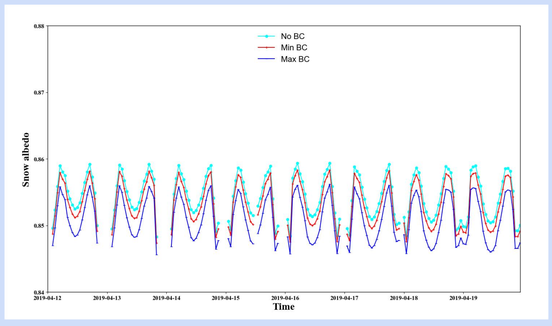


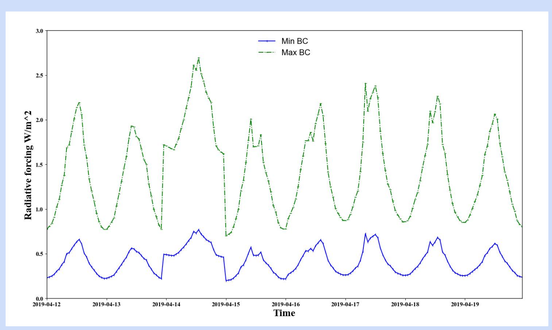




Modeled differences of albedo,sensible heat flux and latent heat flux for sensitivity studies

Snow albedo and radiative forcing(RF)





Modeled snow albedo and radiative forcing due to BC deposition in Ny-Alesund

Conclusions

- The maximum value of BC deposition appears in the western Arctic of Russia (26 ng g^{-1}), and the minimum value appears in Greenland (3 ng g^{-1}).
- A higher value of BC deposition have a substantial impact on snow albedo and energy balance.
- BC deposition in Ny-Alesund can cause 0.001-0.005 snow albedo reduction and 0.5-1.7W/m^2 RF.

References: 1. AMAP. (2015). AMAP Assessment 2015: Black carbon and ozone as Arctic climate forcers. Arctic Monitoring and Assessment Programme (AMAP). Oslo, Norway.
2. Doherty, S. J., Warren, S. G., Grenfell, T. C., Clarke, A. D., & Brandt, R. E. (2010). Light-absorbing impurities in Arctic snow. Atmospheric Chemistry and Physics, 10(23), 11647-11680.·doi:10.5194/acp-10-11647-2010
3. Skiles, S. M., Flanner, M., Cook, J. M., Dumont, M., & Painter, T. H. (2018). Radiative forcing by light-absorbing particles in snow. Nature Climate Change, 8(11), 964-971.·doi:10.1038/s41558-018-0296-5