

# Current-generation Global Climate Models inevitably underestimate pollutant transports to the Arctic

Paper : Sato, Y. et al. “Unrealistically pristine air in the Arctic produced by current global scale models.” *Sci. Rep.* **6**, 26561; doi: 10.1038/srep26561 (2016)

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## Topic of this talk:

- **Black Carbon aerosol (BC) in Arctic simulated by global scale models**
- **Grid refinement study for BC by using a global scale model.**

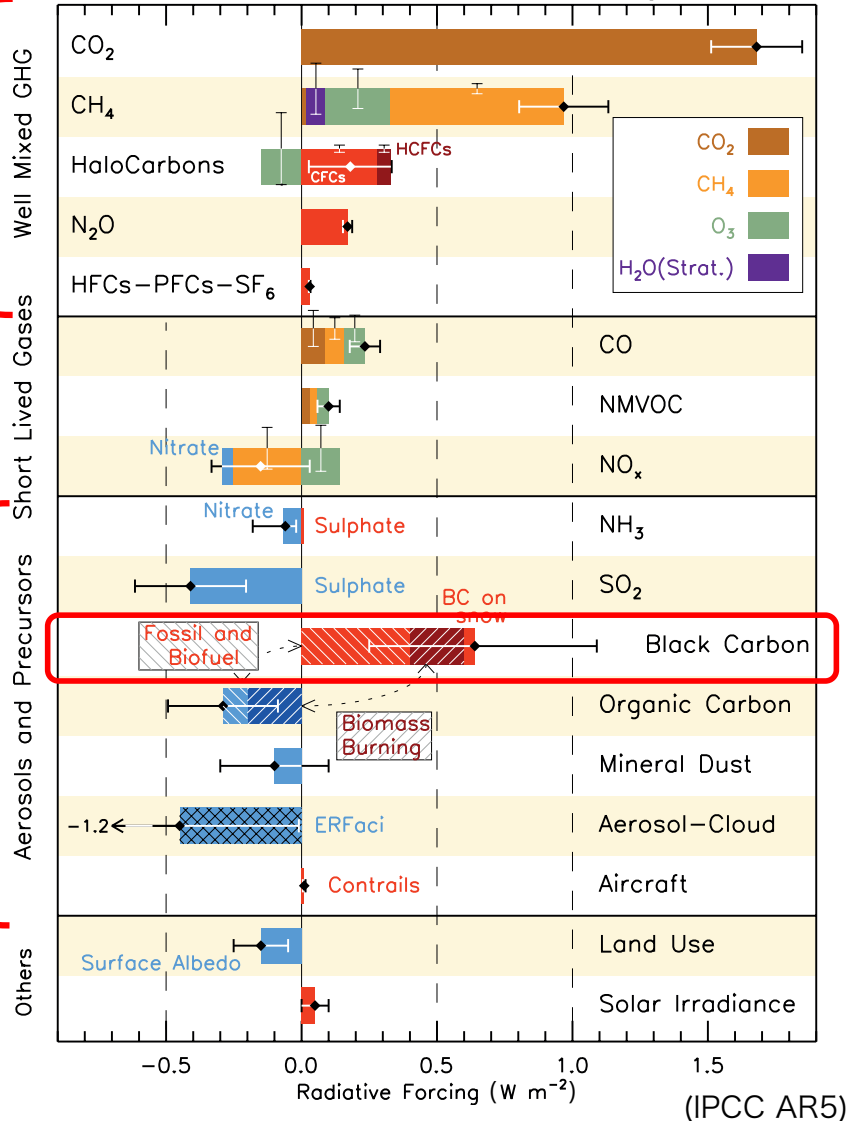
# Unique and large impact of BC

Green house gas

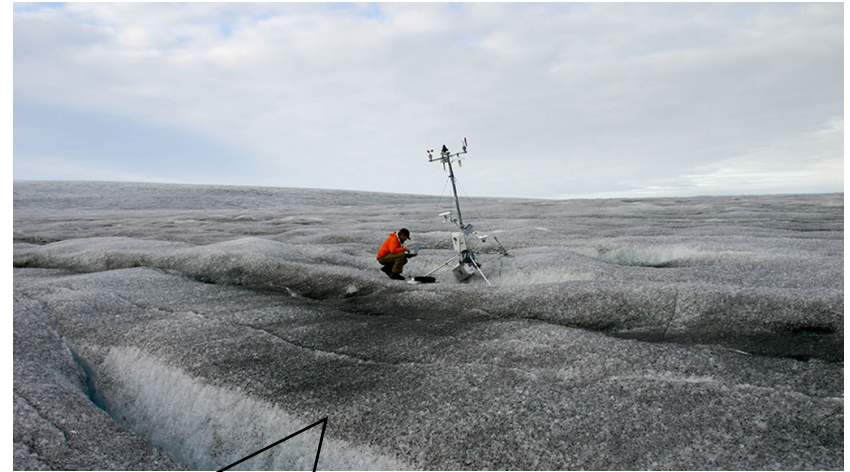
Aerosol

## Radiative forcing (IPCC AR5)

Components of Radiative Forcing



A measurement site in Greenland



Cited from (<http://www.pbs.org/wgbh/nova/next/earth/greenland-and-wildfires/>)

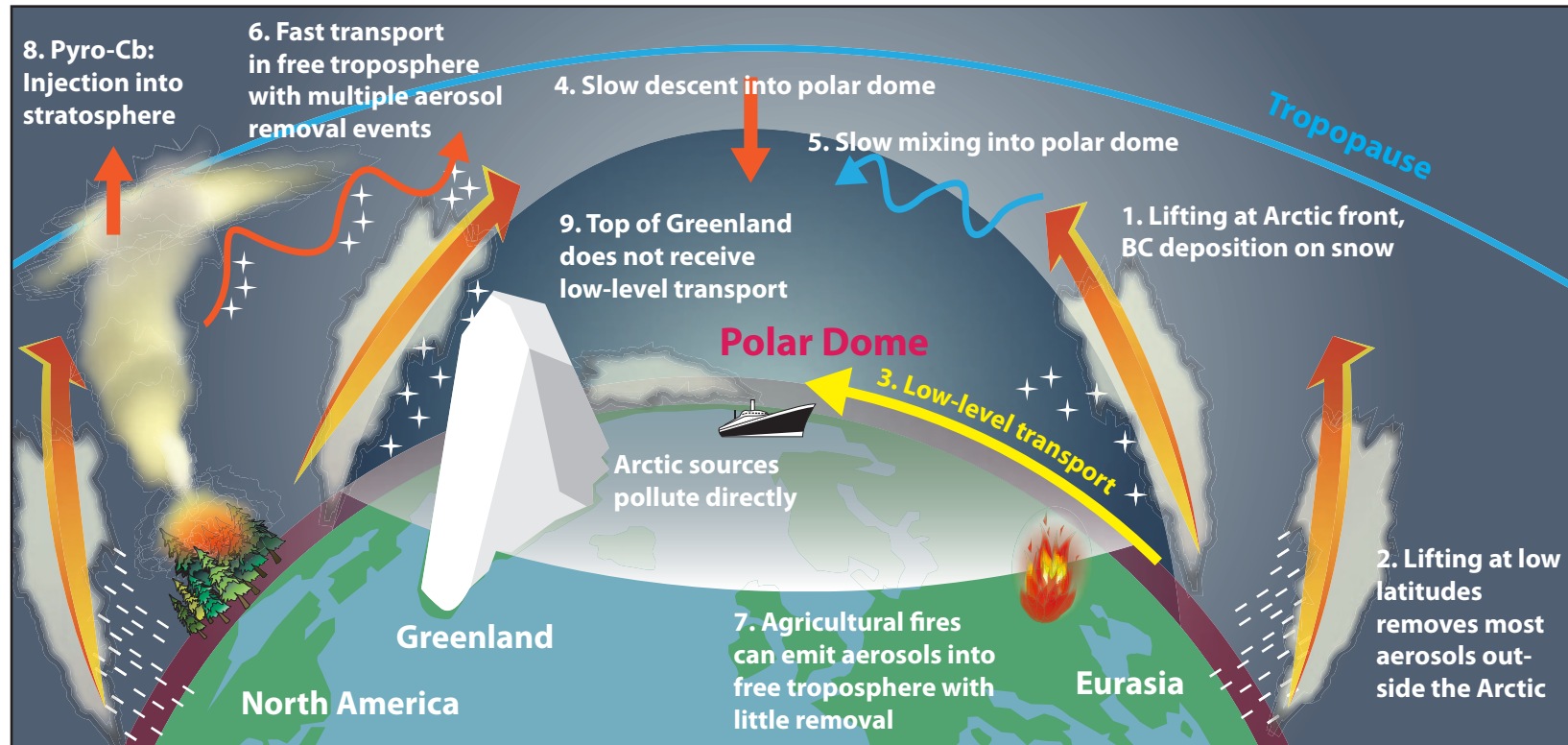
BC in Arctic has large impact on climate through changing albedo of Arctic area

## Radiative Forcing (RF) of BC :

- Opposite to other aerosols
- Magnitude is about 1/3 of CO<sub>2</sub>
- Uncertainties is larger than that of green house gas and other aerosols

# Source of BC in Arctic

## Schematic illustration of BC transport to Arctic



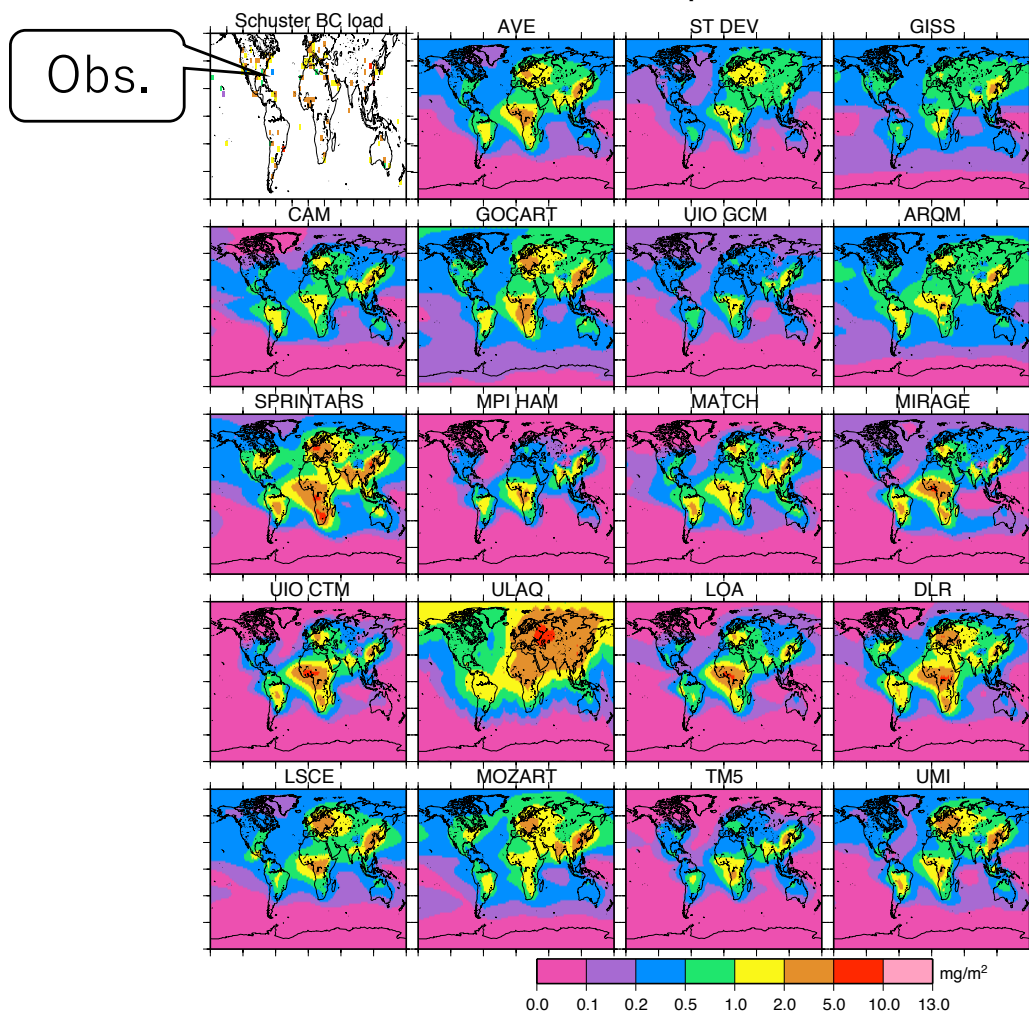
(Quinn et al. 2012)

- There are only a few emission source of BC in Arctic (Law and Stohl, 2007)
- Most of BCs in arctic are transported from mid-latitude (Hirdman et al. 2010)
- Large contribution of low and frontal system to the BC transport to Arctic  
(Barrie et al. 1986, Stohl 2006)

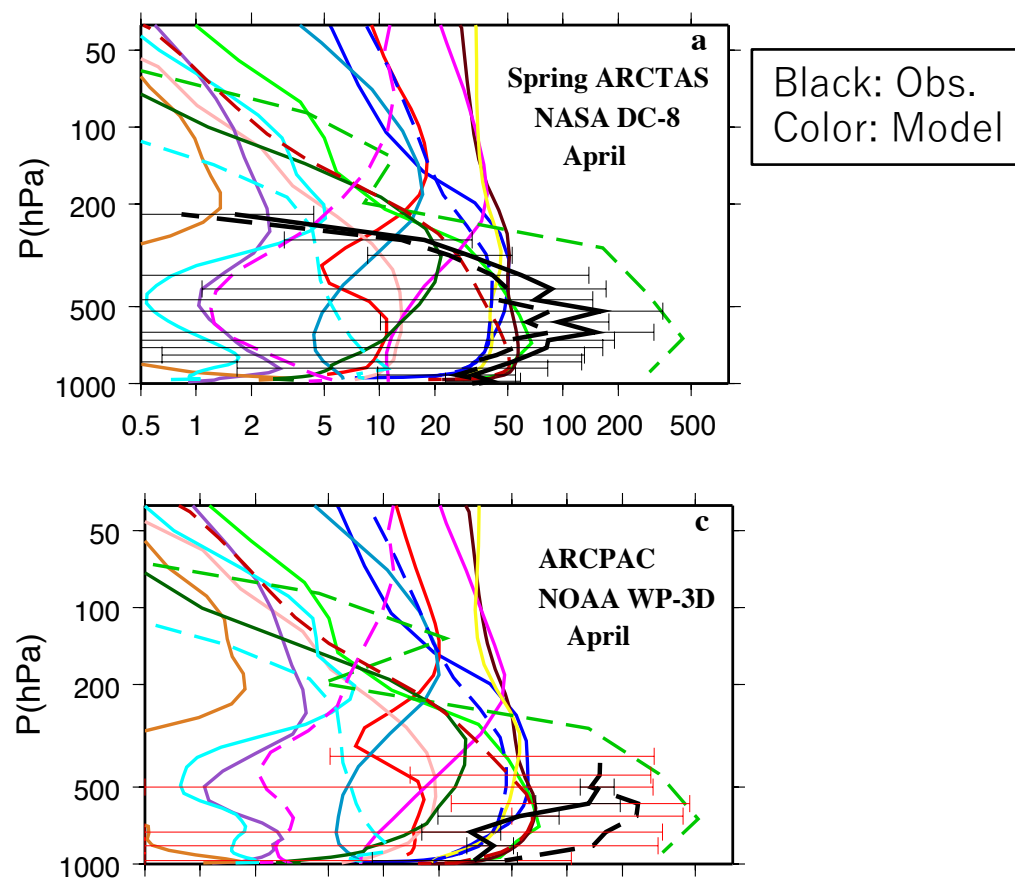


# Global distribution of BC simulated by current generation GCMs

Model v.s. surface observation  
(Model Intercomparison)



Model v.s. aircraft measurement  
(Arctic region)



Koch et al. (2009)

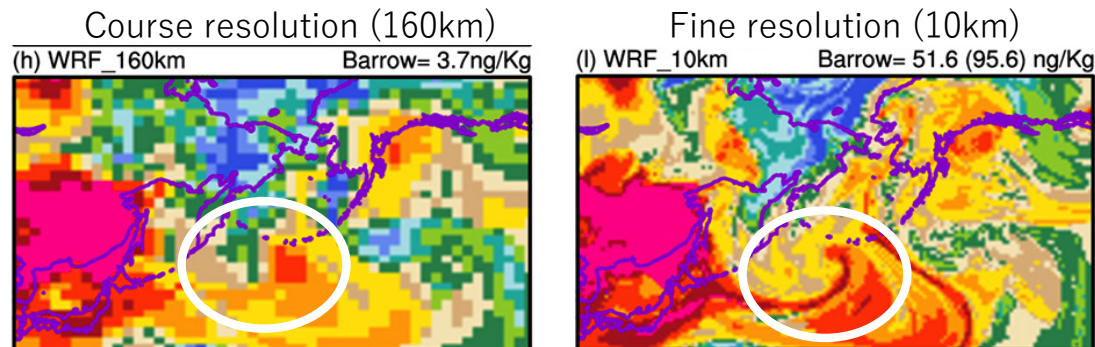
- There is large variability of BC distribution among the GCMs
- Most of GCMs underestimate BC in Arctic region

# Previous studies

## Reason of the underestimation suggested by previous studies

- **Uncertainties in BC's microphysical process**
  - Aging (e.g., Vignati et al, 2010, Wang et al. 2013, Matsui et al. 2013)
  - Wet deposition (e.g., Vignati et al. 2010, Garrett et al. 2011, Browse et al. 2012)
  - Dry deposition (Wang et al. 2013) etc.....
- **Uncertainties of emission inventory** (Wang et al. 2014, Cohen et al. 2014)
- **Resolution of model** (Ma et al. 2014, 2015, Allen et al. 2014, Liu et al. 2016)

## Concentration of BC simulated by Regional model(WRF)



Ma et al. (2014)

Low resolution models cannot resolve detailed structure of the low and frontal system, and detailed structure has impacts on BC transport .....

But, the simulation with fine resolution is limited to one targeting area

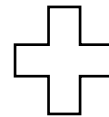
# Purpose

- To investigate effects of grid resolution on the BC in Arctic by using a “global scale cloud system resolving model”
- Estimate contribution of low and frontal systems to the BC in Arctic.

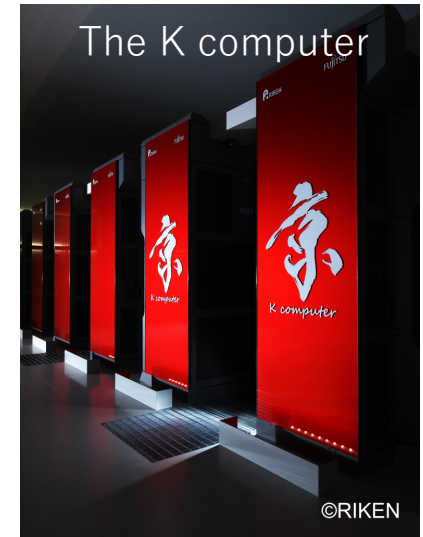
Model (NICAM-SPRINTARS)



Tomita and Satoh (2004), Satoh et al. (2008), Satoh et al. (2014)



Takemura et al. (2005)



## Experimental setup

Duration time : 2 week (from Nov. 17 to Dec. 1 of 2011) [analyzed last 10 days]

Resolution : [Horizontal] 3.5km, 14km, 56km, [Vertical] 38 layers

Microphysics : 1-moment bulk (Tomita, 2008), (3.5km 14km), LSC+CP (Chikira, 2013)(56km)

Initial condition (dynamics) : NCEP-NFL (Kalnay, 1996)

Initial condition (aerosols) : Interpolated from the result of NICAM-SPRINTARS for two years with 56 km grid resolution

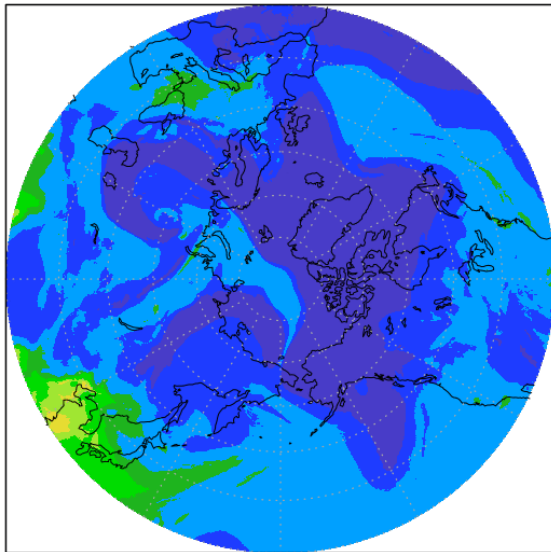
Emission inventory :

Anthropogenic : EDGAR-HTAP\_V2.2 (Janssens-Maenhout et al., 2015)

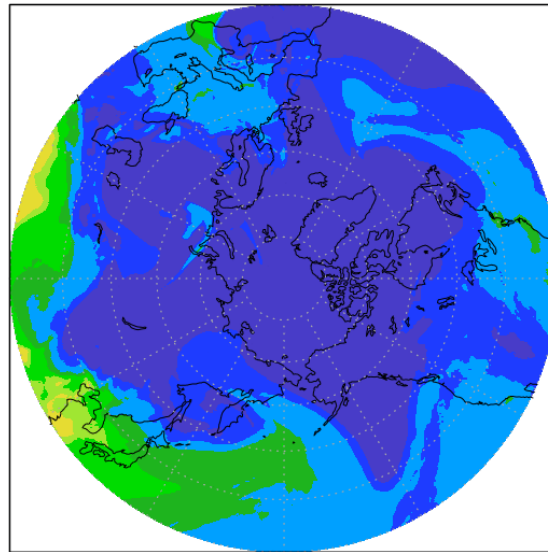
Biomass burning : GFEDv3 (Randerson et al. 2013)

# Animation of vertically accumulated BC (last 10 days)

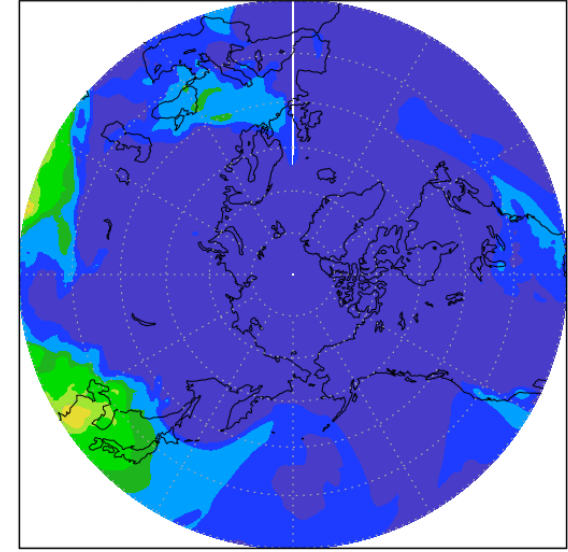
dx=3.5km(GL11)



dx=14km(GL09)



dx=56km(GL07)

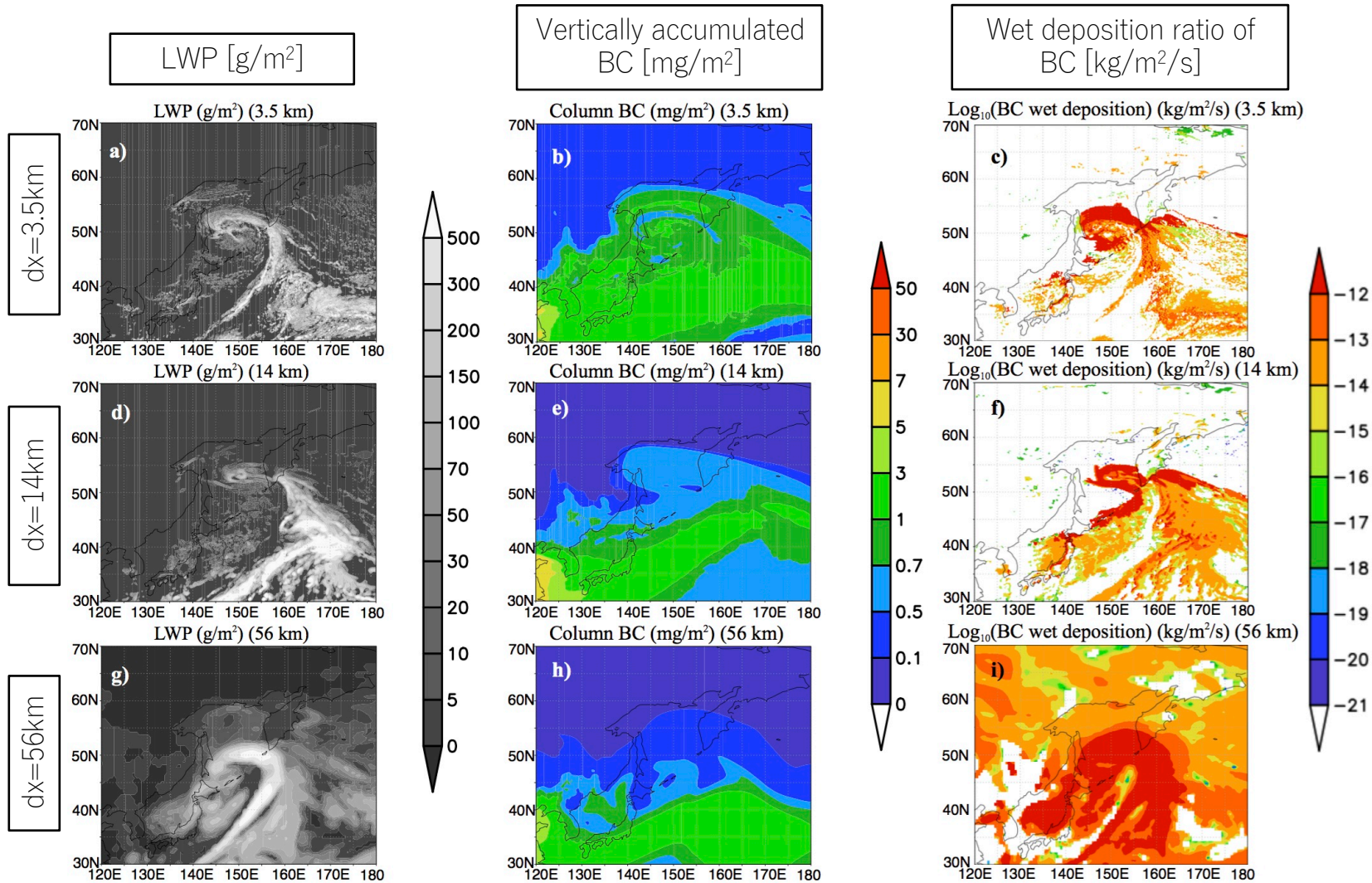


0 0.3 0.5 1.0 1.5 3 4 7 10 30 [mg/m<sup>2</sup>]

- Amount of BC transported to Arctic is increased with fining resolution
- Mid-latitude low and frontal system has large contribution to the BC transport



# Structure of Low and frontal system



Fine resolution  
Contrast between cloud and cloud free area is clear

Wet deposition free area is wider

→ Large amount of BC is transported northward

Coarse resolution  
The contrast is not clear

Wet deposition occurs over wide area

→ Small amount of BC is transported northward

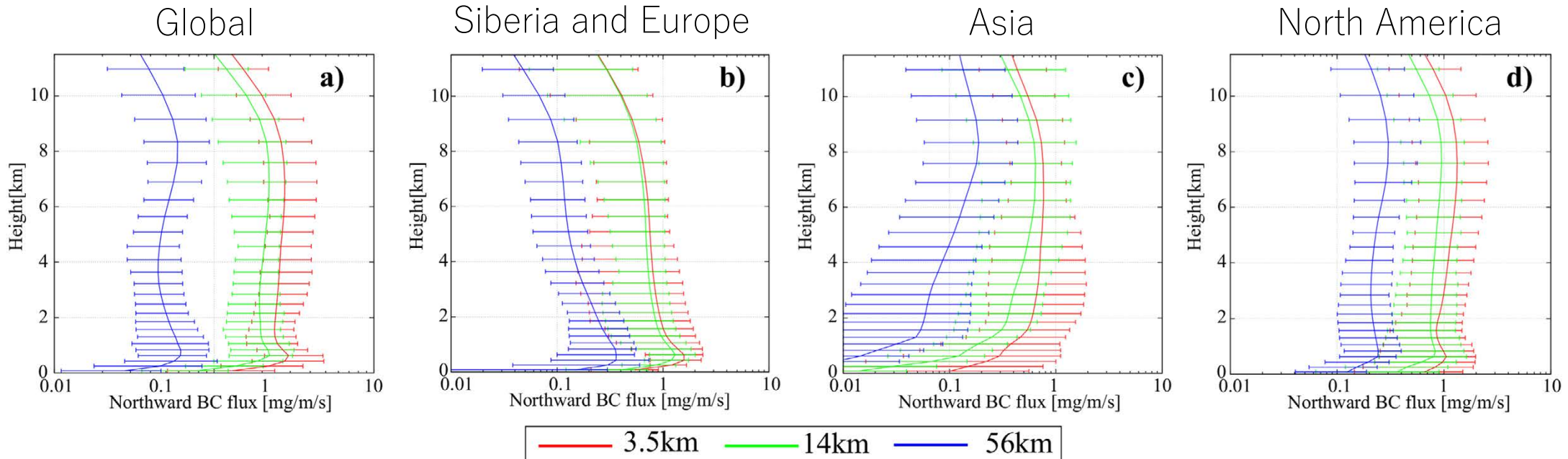
# Contribution of lows and frontal systems

Resolution	Northward BC flux at 60 N°(kg/s)	Contribution of lows and frontal systems(%)
3.5km	35.5	58.17
14km	27.66	57.63
56km	8.15	55.95

\* Low and Frontal systems were extracted by the method of Miyamoto et al. (2014)

- Northward mass flux is increased with fining grid resolution
- Contribution of mid-latitude low and frontal system also increases with fining grid resolution

# Regional variability of northward flux of BC



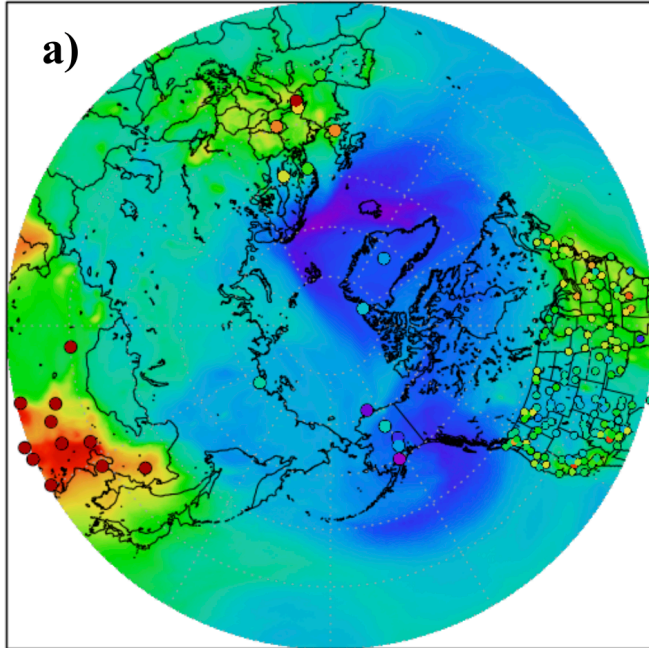
- Increase of the BC transportation occurs over whole layer
- The difference between 3.5km and 14km is much smaller than that between 14km and 56 km.



# Model v.s. surface observation

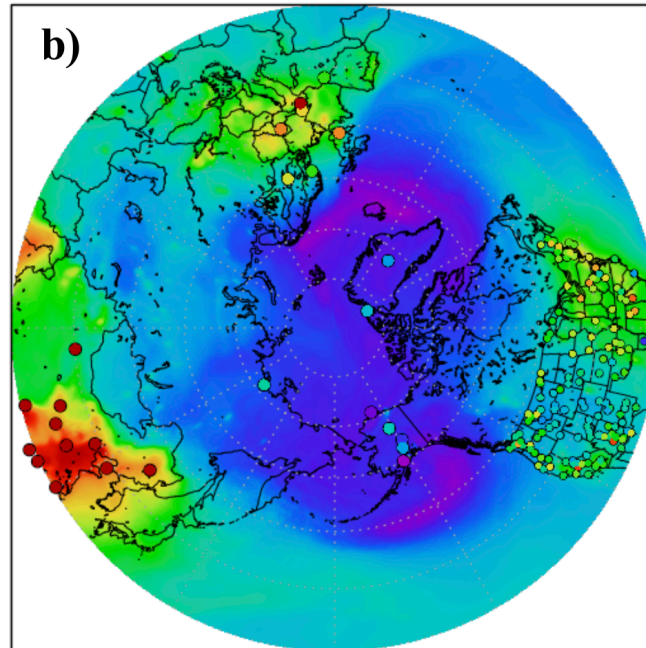
dx=3.5km(GL11)

Log(Surface BC mass) (ng/m<sup>3</sup>) (3.5 km)



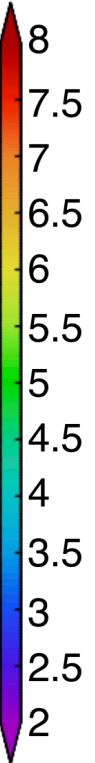
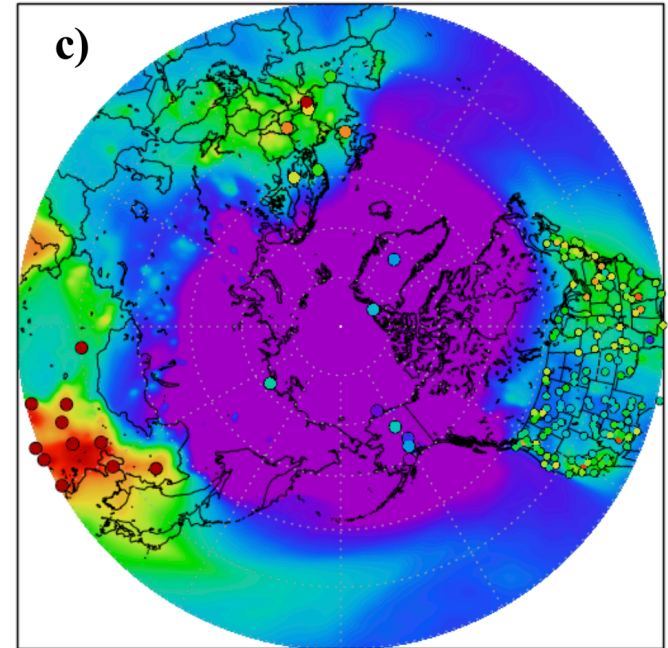
dx=14km(GL09)

Log(Surface BC mass) (ng/m<sup>3</sup>) (14 km)



dx=56km(GL07)

Log(Surface BC mass) (ng/m<sup>3</sup>) (56 km)

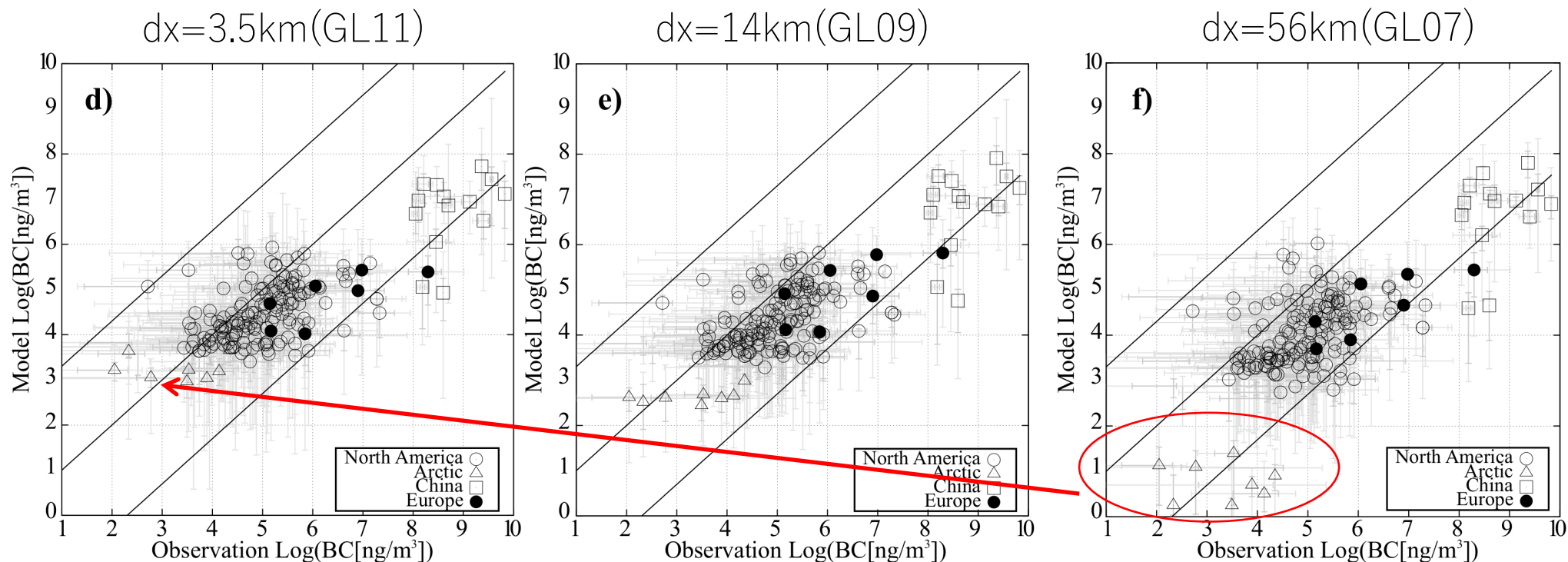


Shade : Model(Averaged during last 10 days)    ○ : Observation (Averaged during one month. 2011 Nov.)

Observation data :

North America : IMPROVE, CABM , Asia : CAWNET、 Europe : EUSAAR

- Underestimation of the model is reduced with fining grid resolution



Underestimation is reduced by fining resolution

△ : Arctic , ○ : North America, ● : Europe, □ : Asia, |——| : 25 ~ 75 percentile

Difference between model and Observation (Obs.)/(Model) [ng/m<sup>3</sup>]

Resolution	North America	Europe	China	Arctic
3.5km	1.1200	1.3174	1.3236	1.0299
14km	1.1531	1.2723	1.3136	1.2542
56km	1.2486	1.3693	1.3401	6.1050



# Summary

- We investigated effects of horizontal grid resolution on BC transport to Arctic
- By fining grid resolution, the underestimation of BC was reduced.
- The reduction was derived from the improvement of the detailed structure of low and frontal system

Main message of this study is ...

Global scale modeling with fine grid resolution is required for accurate representation of aerosol in Arctic and in Antarctic

Acknowledgement :

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# Thank you!

Information of paper :

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