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Black Carbon Arctic Climate

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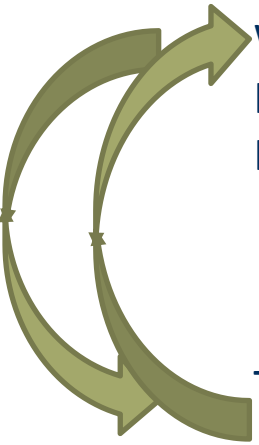
Latest assessment on this topic is the report from AMAP

The Impact of Black Carbon on Arctic Climate

Available now in a store near you!

Common central questions for this type of work are:



What produces BC (i.e. economic sectors, geographical distribution)?
How is BC transported away from the sources, and then what (i.e. life cycle)?
In what way is BC interacting with the energy fluxes (directly, indirectly)?

Ultimately……

To what extent is BC driving the climate?

The only viable way to answer this question is by numerical models.

Tool for designing strategies

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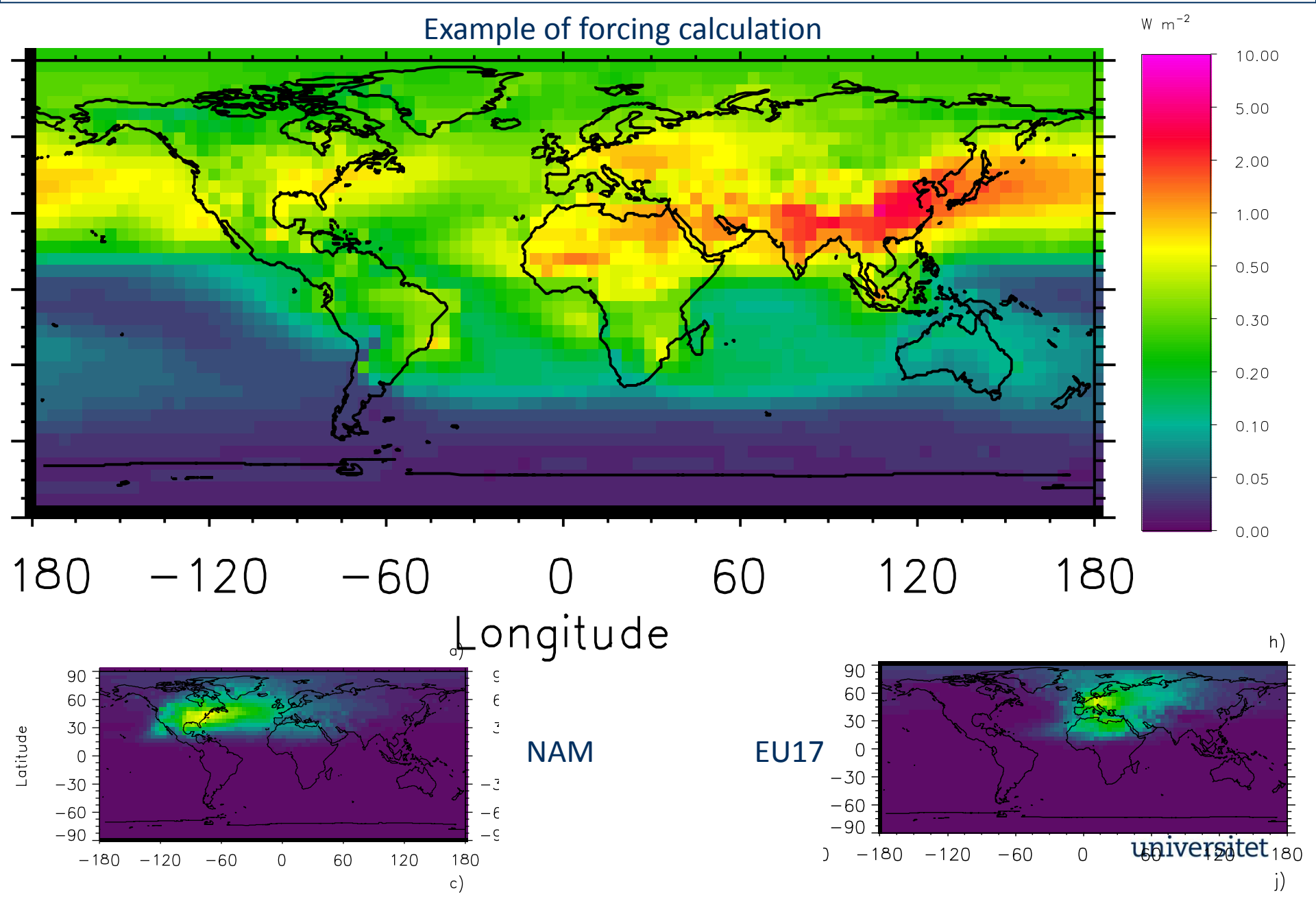
Radiative forcing (direct effect only, Wm^{-2}) of regional and global BC emissions from fossil fuels and biofuels (Rypdal et al., Tellus, 2009)



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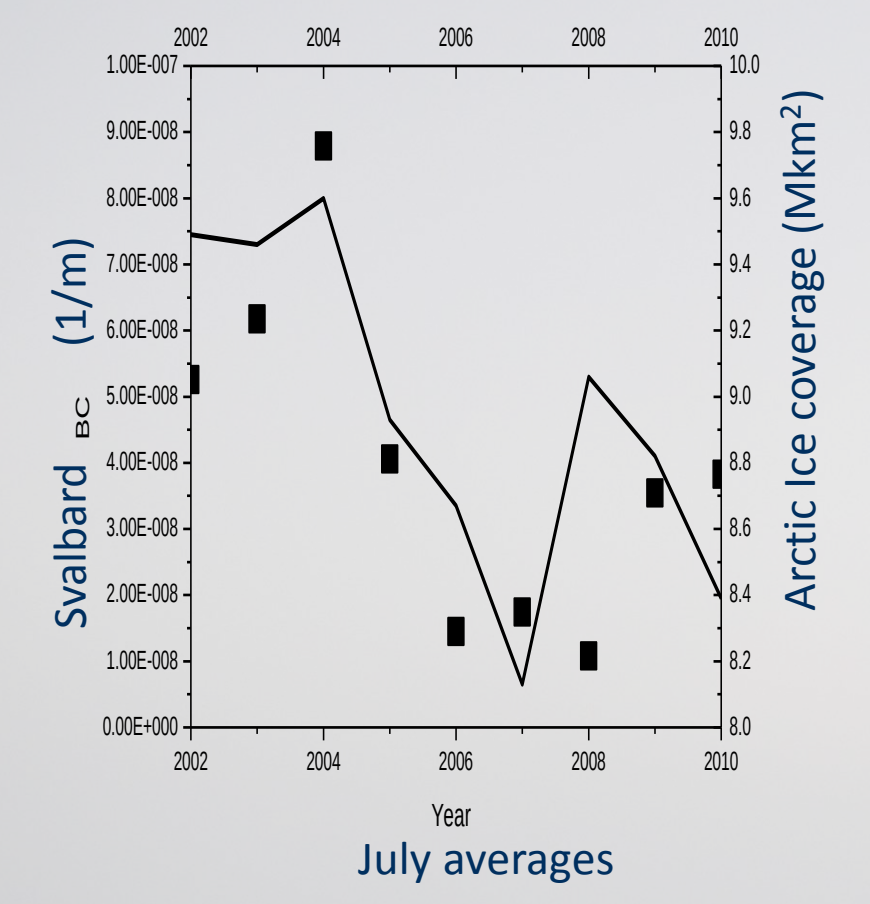
My objective with this presentation is to put things such as forcing calculations into context by elaborating with different scales and perhaps give a sort of behind-the-scene feeling with respect to BC and the Arctic.

We may start with the simplest model possible, a relationship between two variables

Note: This is perfectly real data spanning almost a decade in time

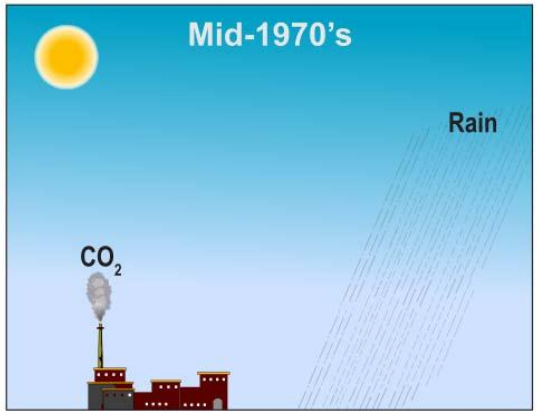


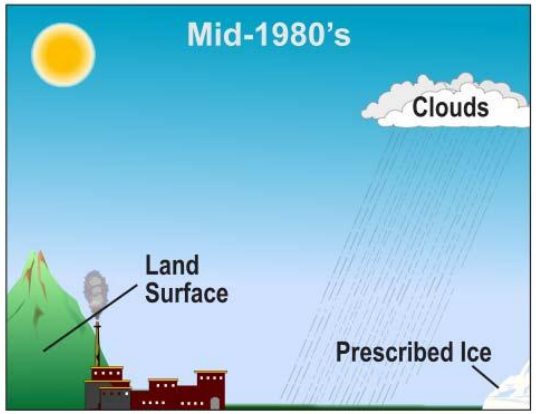
Obvious conclusion would be; more BC in the air is favorable to the sea ice cover.

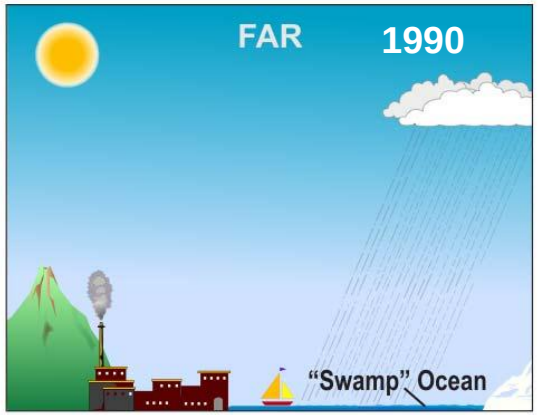
The problem is of course the lack of understanding that this relation is built on, and models must continuously be fed with new knowledge.

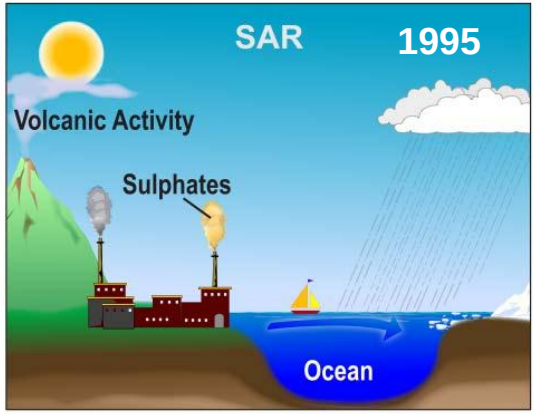
Photo: Sebastian Gerland, NPI

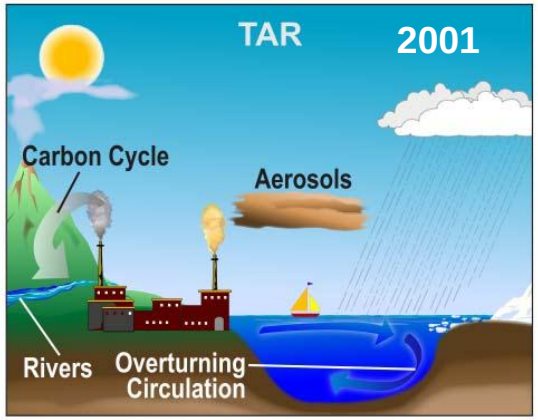
The World in Global Climate Models

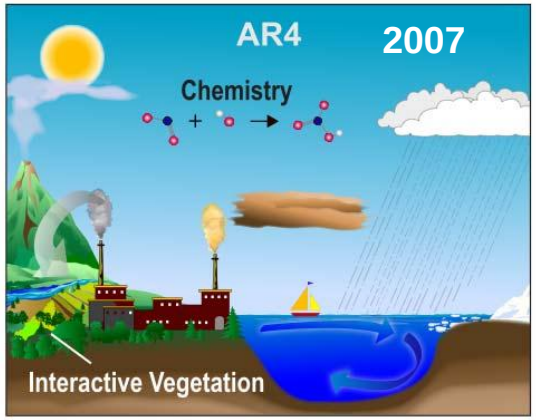




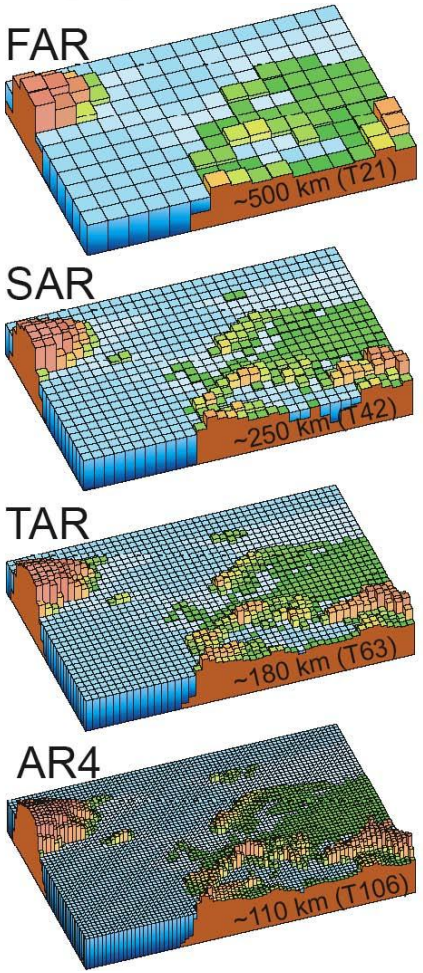








Numeric approximation



1990

1995

2001

2007

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IPCC AR4

Sometimes too much details can make it hard to see small things.
To introduce BC in the Arctic, we together will make a climate model.
Air intakes on the roof of the Zeppelin station

A very simplified (but useful) climate model
Only 2 equations, I promise!

Sanja Forsström
Digging snow

Albedo =0.3

Solar constant 1370 W m^{-2}

Energy received by the Earth from the Sun is:
S=1370*(1-albedo)*(Area of the disc)

Every thing with a temperature radiates energy.

Energy leaving from the Earth to space is:
$E=\sigma T^4$*(Area of a sphere)

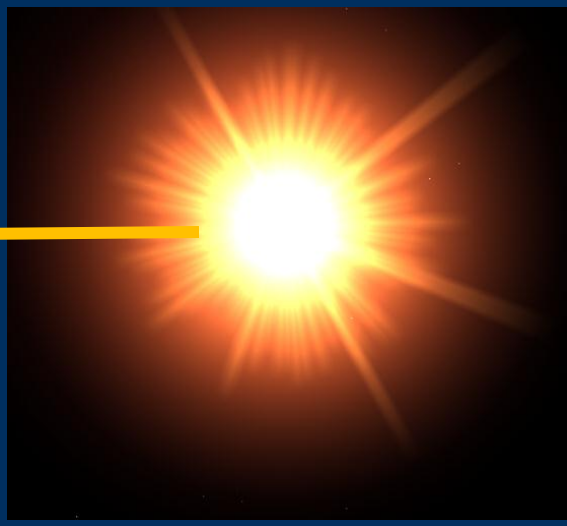
$\sigma = 5.67x10^{-8} Wm^{-2} K^{-4}$

Over some time S must equal E :
1370 (1-albedo)*(Area of disc)=5.67 10^{-8} T^4 (Area of sphere)

$$\frac{\text{Area of sphere}}{\text{Area of disc}} = 4$$

Albedo =0.3

Area of Disc



Solar constant 1370 W m^{-2}

$$\frac{1370*(1-albedo)}{5.67\ 10^{-8}*4} = T^4$$

Albedo = 0.3 then T=255K (-18C)

Energy leaving from the Earth (including an atmosphere) to space:
$E=\sigma T^4*$(Area of a sphere) (1-GG)

$$\frac{1370*(1-albedo)}{5.67\ 10^{-8}*4*(1-GG)} = T^4$$

$$\frac{1370*(1\text{-albedo})}{2.27\ 10^{-7}\ *(1-\ GG)} = T^4$$

Average temperature on Earth ca 15 C,
which gives GG=0.385

CO2 contributes about 10% “pre-industry” GG.
A doubling of that corresponds to a temperature change of about 4 $^1/_2$ degrees Celsius.

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$$\frac{1370*(1\text{-albedo})}{2.27\ 10^{-7}\ *(1-\ GG)} = T^4$$

Changing the planetary albedo by 1% will change the average temperature by about 1/3 of a degree.

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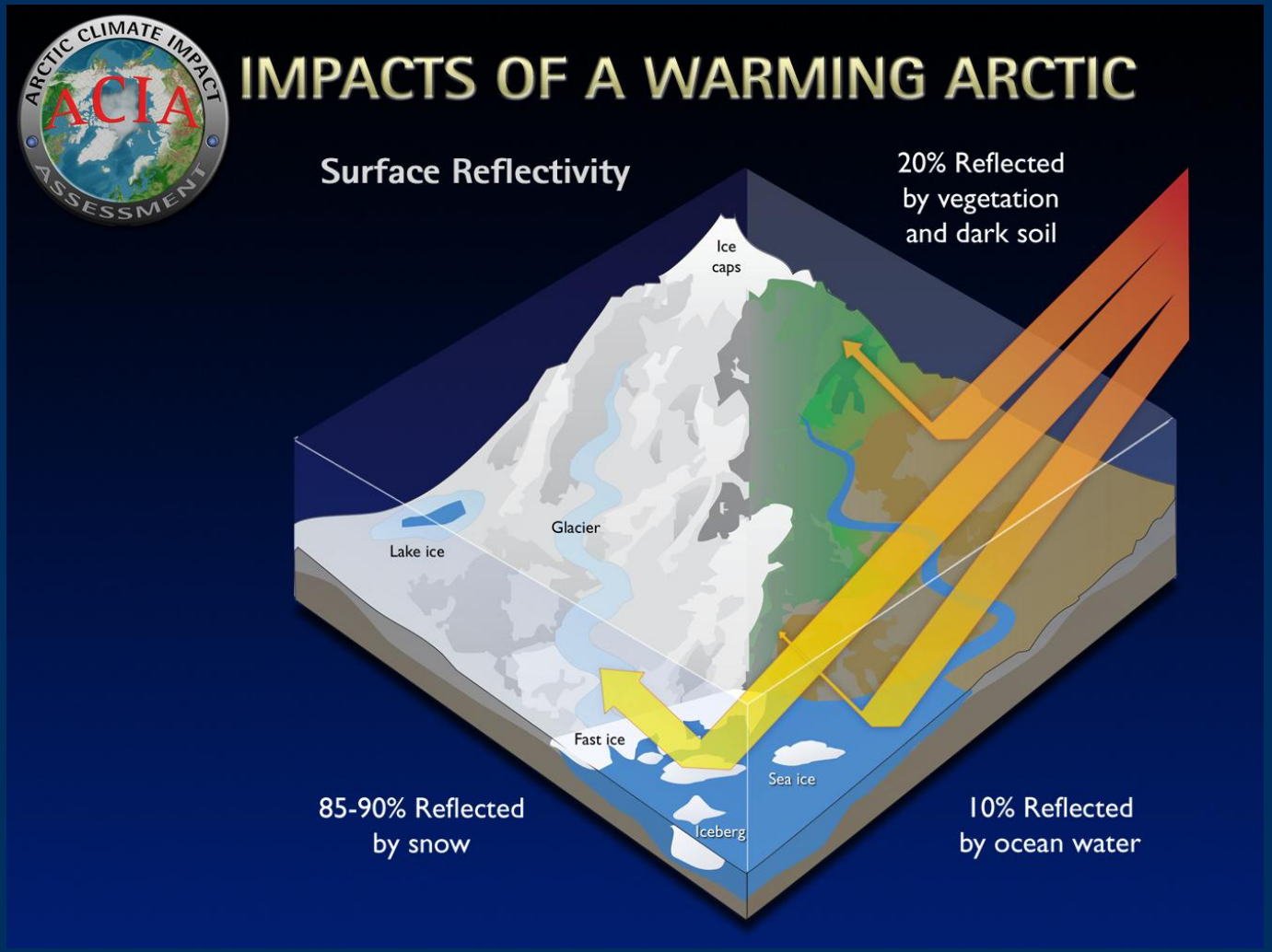
Small changes in Albedo can be very important for climate on the global scale



So can we relate a % change in albedo with BC concentrations in snow?

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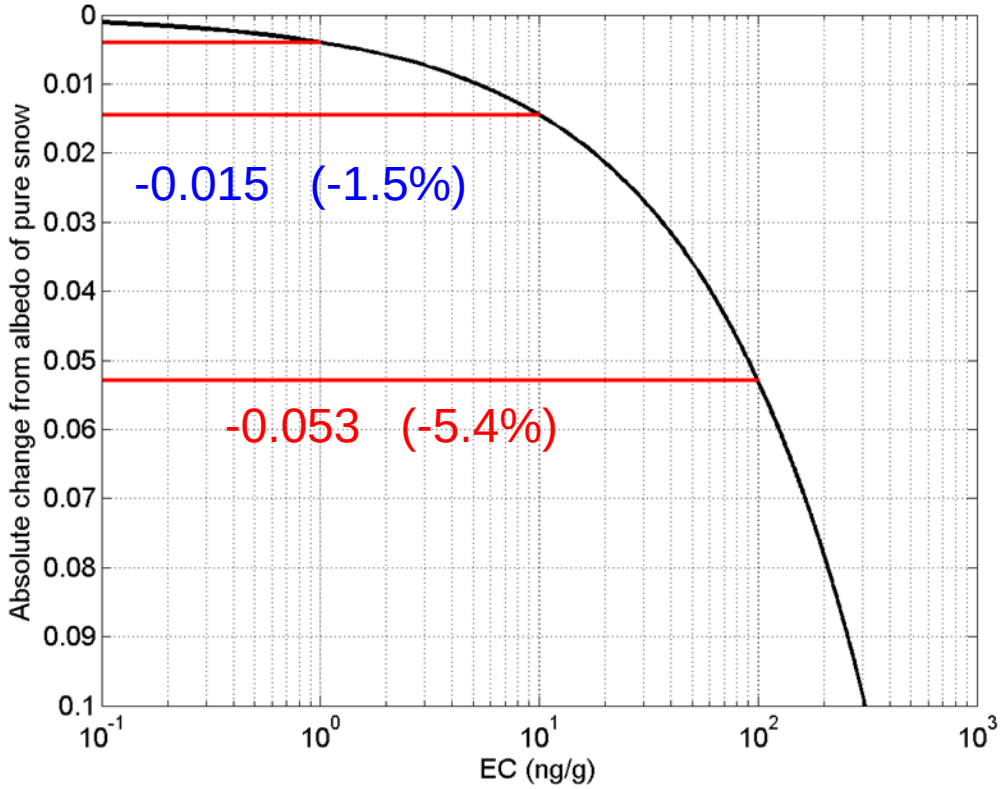
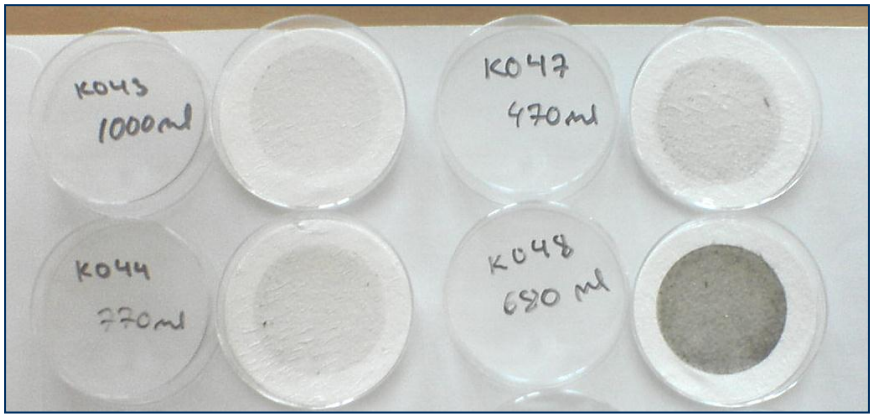
Våre observasjoner (LOTUS)

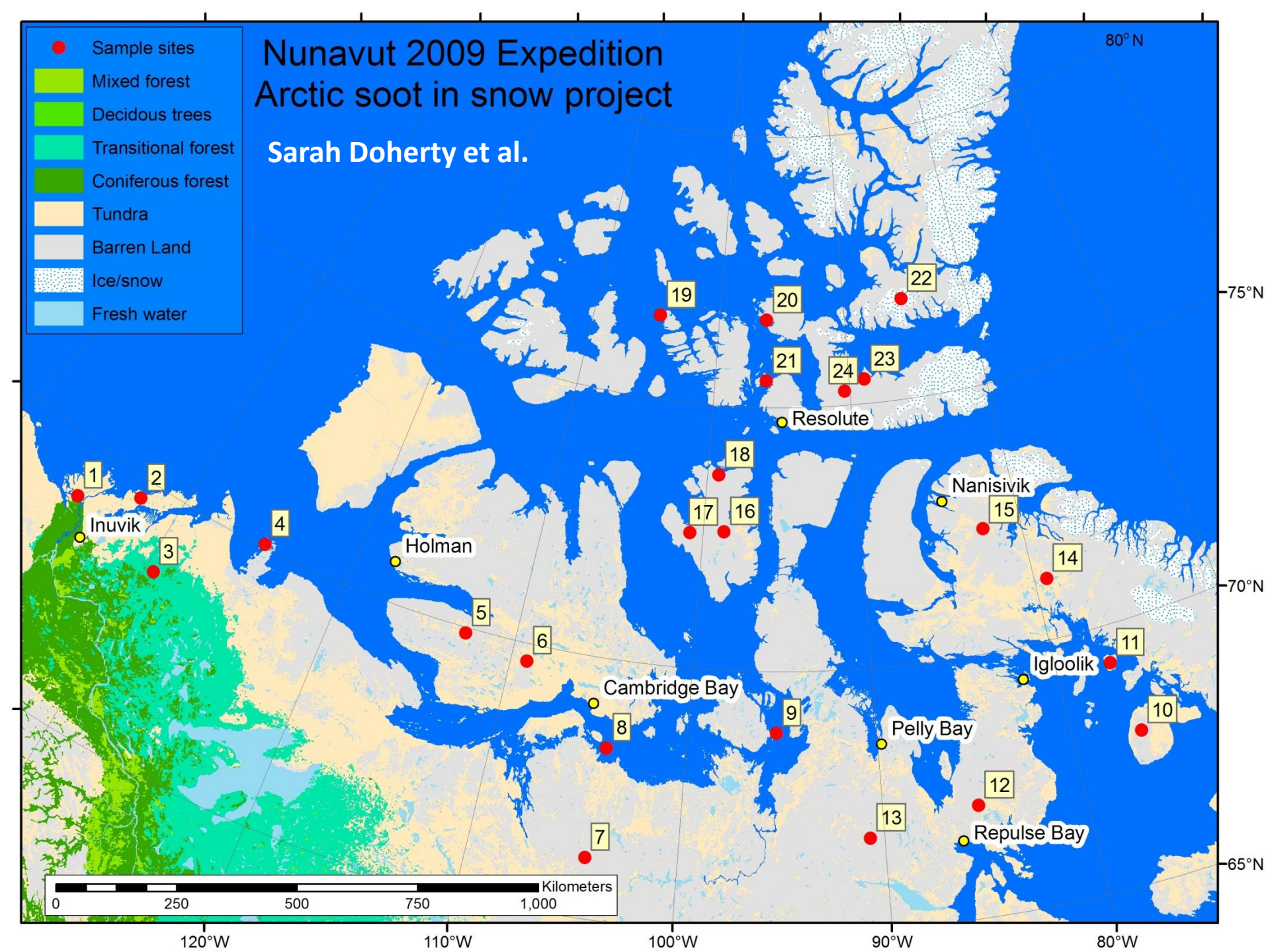


Pedersen et al., in prep.



Digging snow

Christina Pedersen


Sample sites
Mixed forest
Decidous trees
Transitional forest
Coniferous forest
Tundra
Barren Land
Ice/snow
Fresh water
Nunavut 2009 Expedition
Arctic soot in snow project
Sarah Doherty et al.
80° N
75°N
70°N
65°N
120°W
110°W
100°W
90°W
80°W
Kilometers
0
250
500
750
1,000
Inuvik
Holman
Resolute
Nanisivik
Igloolik
Cambridge Bay
Pelly Bay
Repulse Bay
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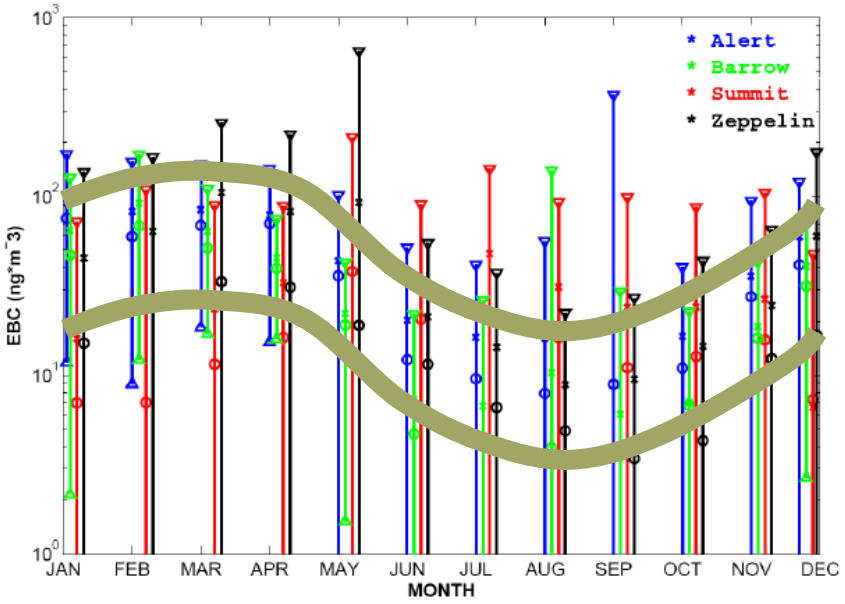
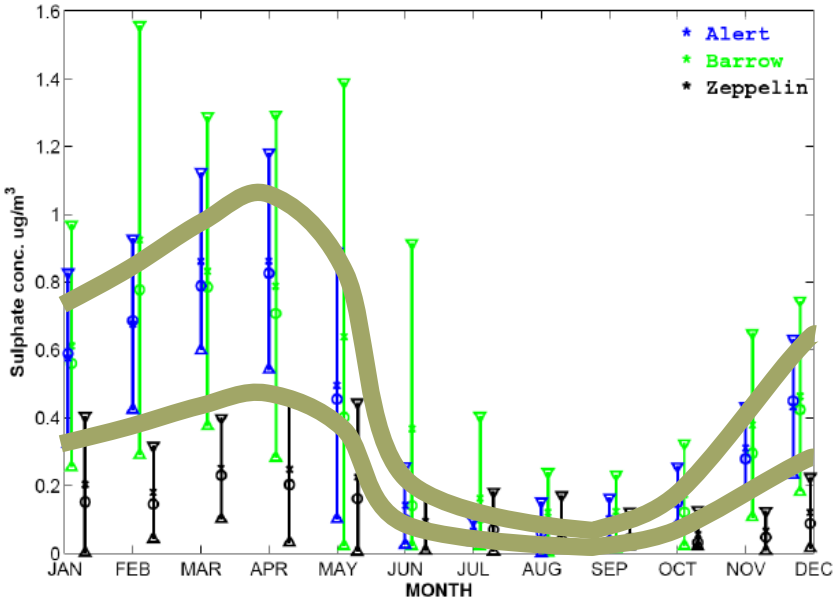
How much is actually a ng/g?

BC concentrations, by mass, are typically lower in the air than in the snow.

Despite low values there is a very strong seasonal variation in the levels of air pollution in the Arctic.





Sometimes very polluted air can reach the Arctic. The most extreme case ever recorded was in May 2006

Hirdman et al., 2010

26 April 02 May

Photo: Anki Engvall Stjernberg

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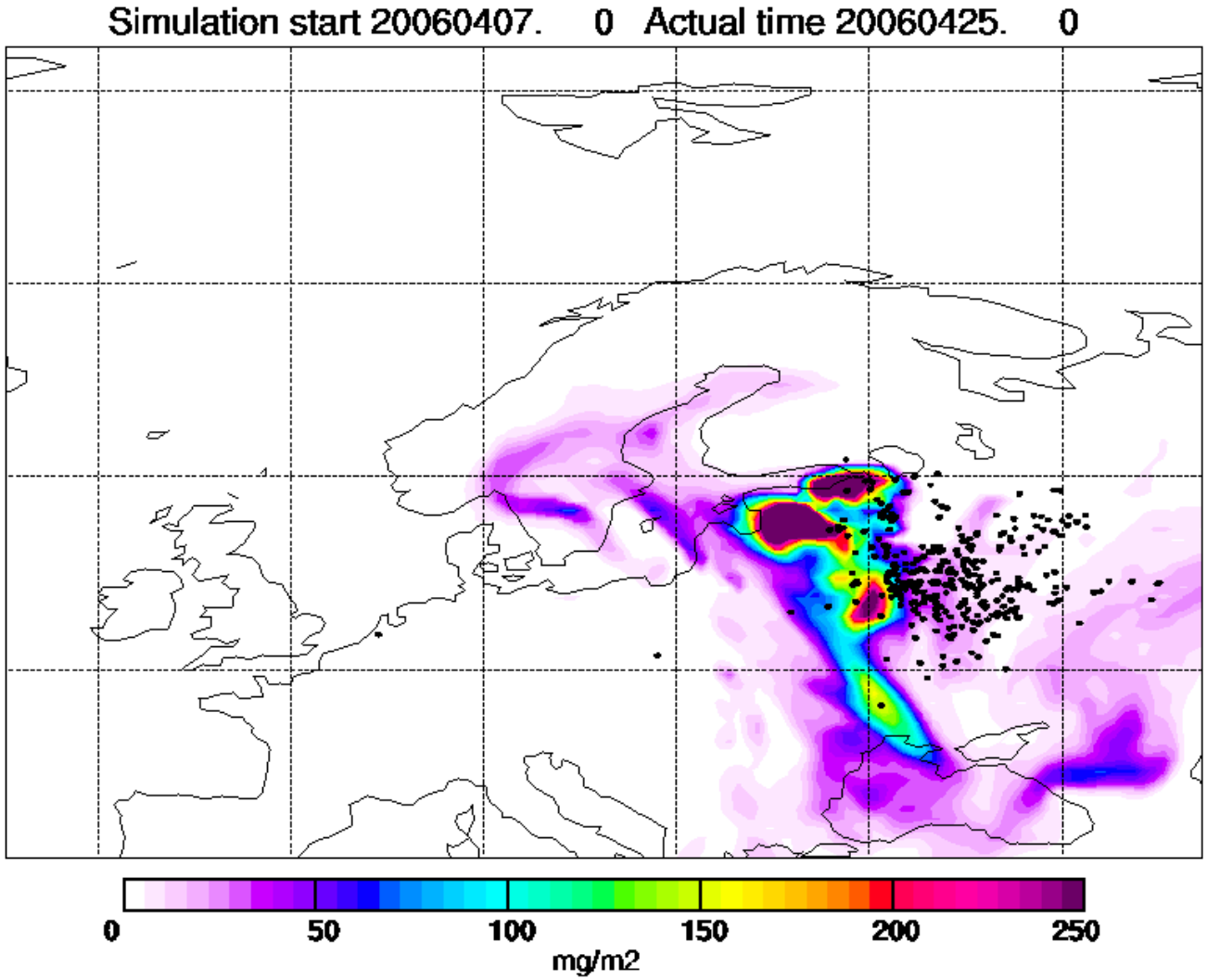

Andreas Stohl et al.

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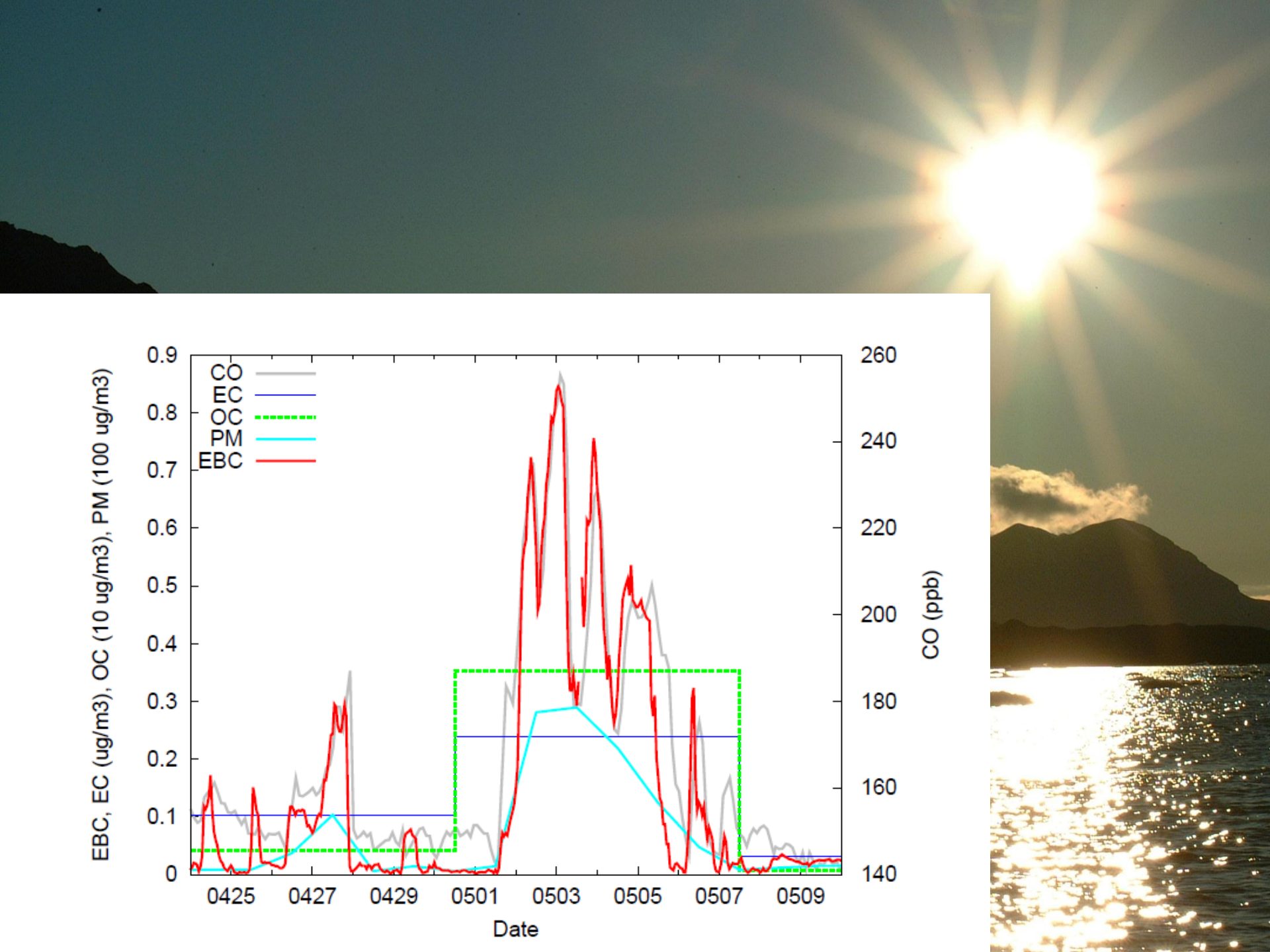

CO
EC
OC
PM
EBC
EBC, EC (ug/m3), OC (10 ug/m3), PM (100 ug/m3)
CO (ppb)
Date
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
260
240
220
200
180
160
140
0425
0427
0429
0501
0503
0505
0507
0509

BC is far from a boundary layer issue

Aerosol layer on 14 April, 2007

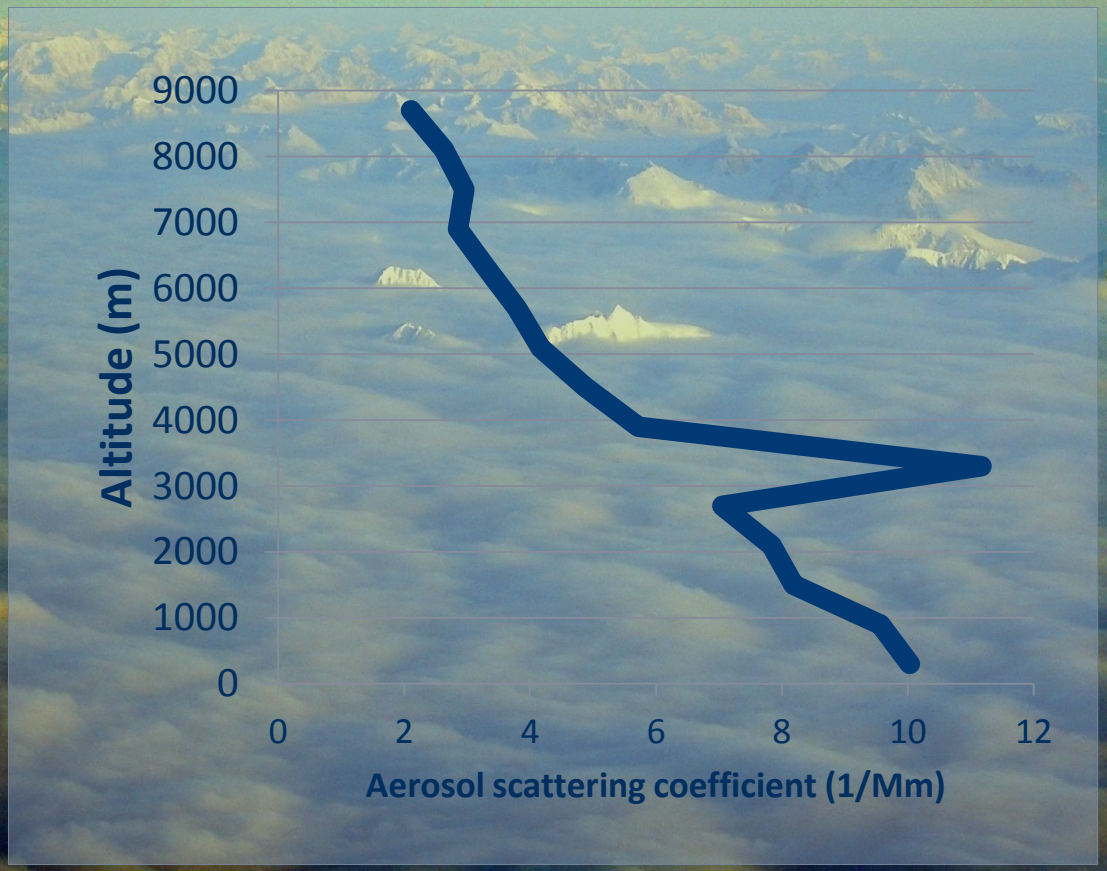
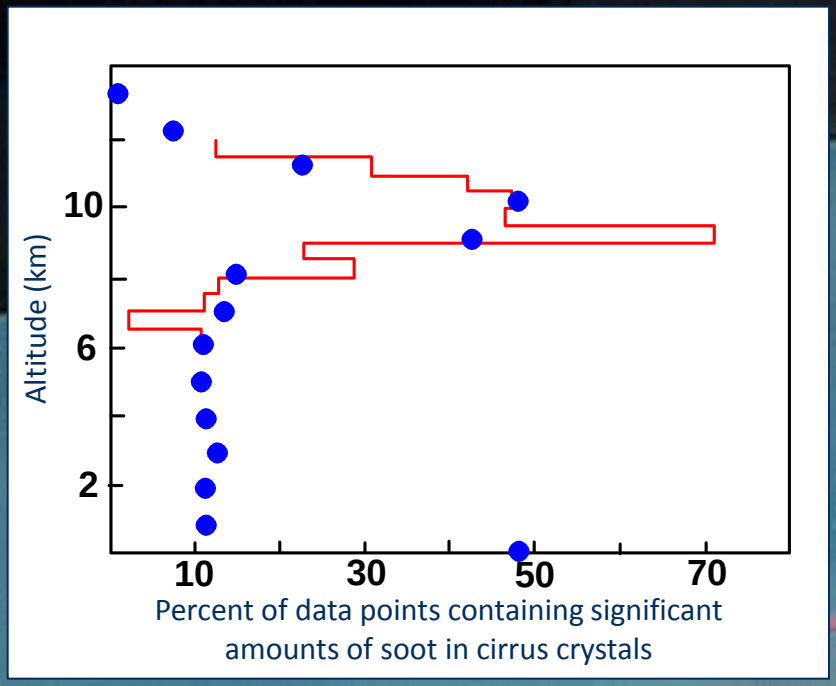


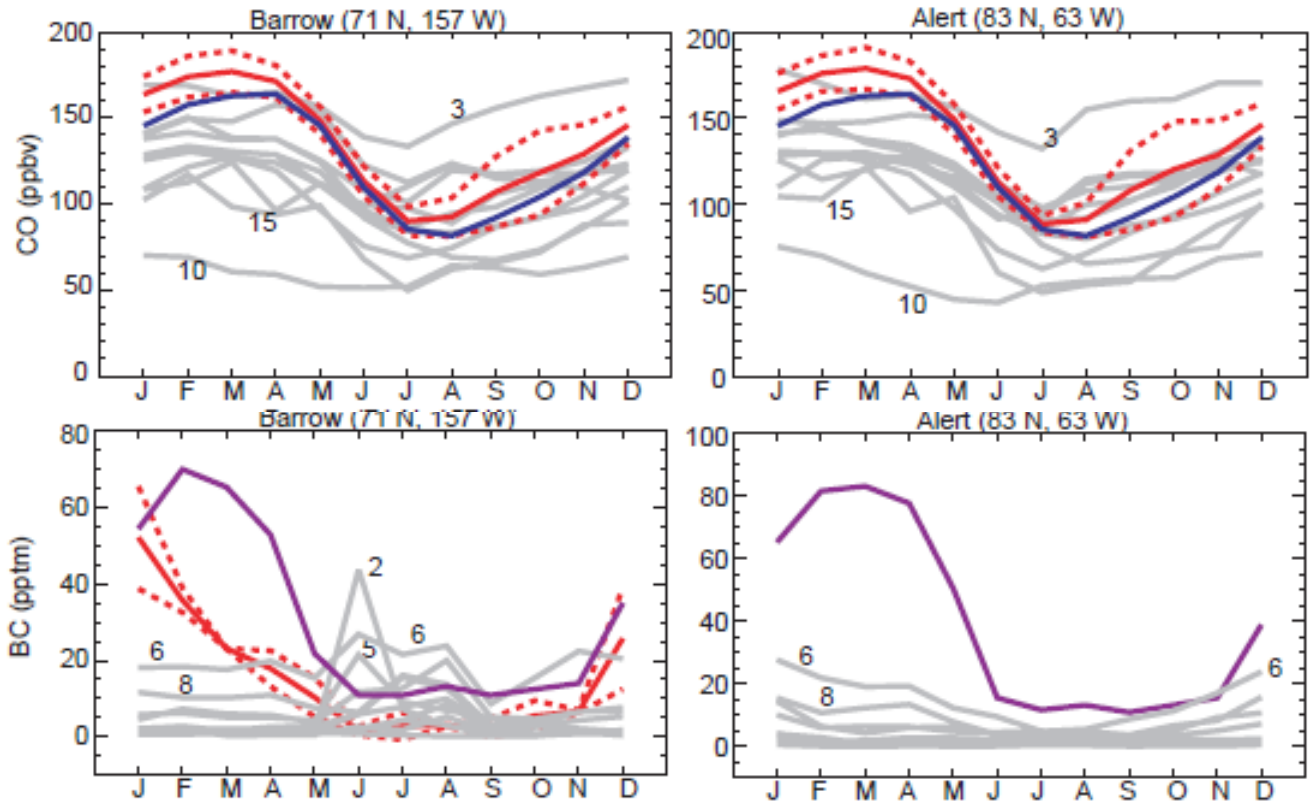
Photo: Andreas Minikin



SULFUR 2,
AEROCONTRAIL etc

Title for this session started “What do we know…

By comparing models with observations we can get a feeling for our level of understanding.



Shindell et al., 2008

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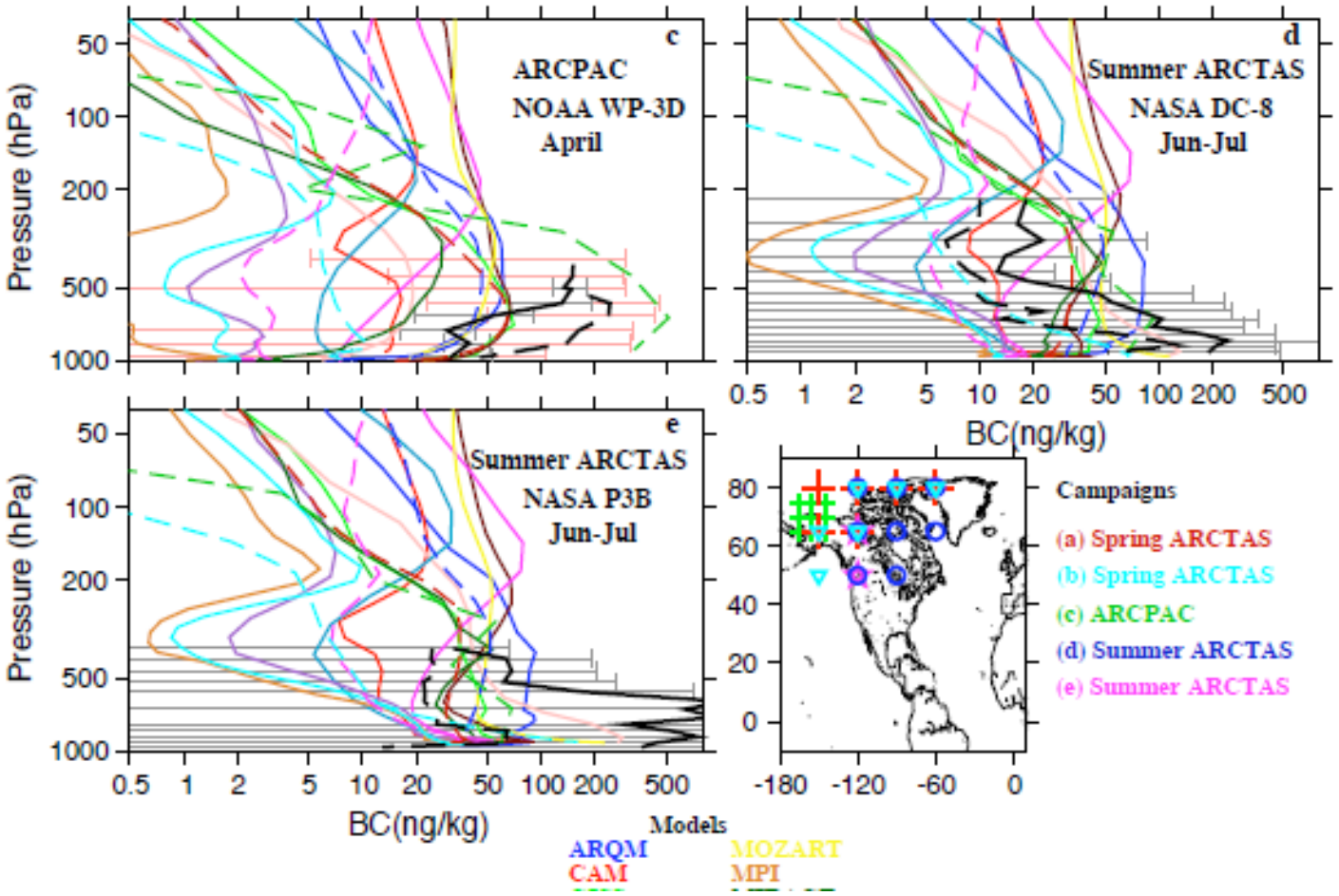
Examples of vertical intercomparisons



Koch et al., 2010

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In summary

Small changes in albedo can have significant impact on temperature.

Approximately 10 ng/g BC is needed to change the albedo of snow by 1%
A ng/g BC is very little

Most importantly: we must acknowledge that “eyeballing” climate forcing on a global scale is not the same as getting it right on a regional scale. Process understanding is missing.

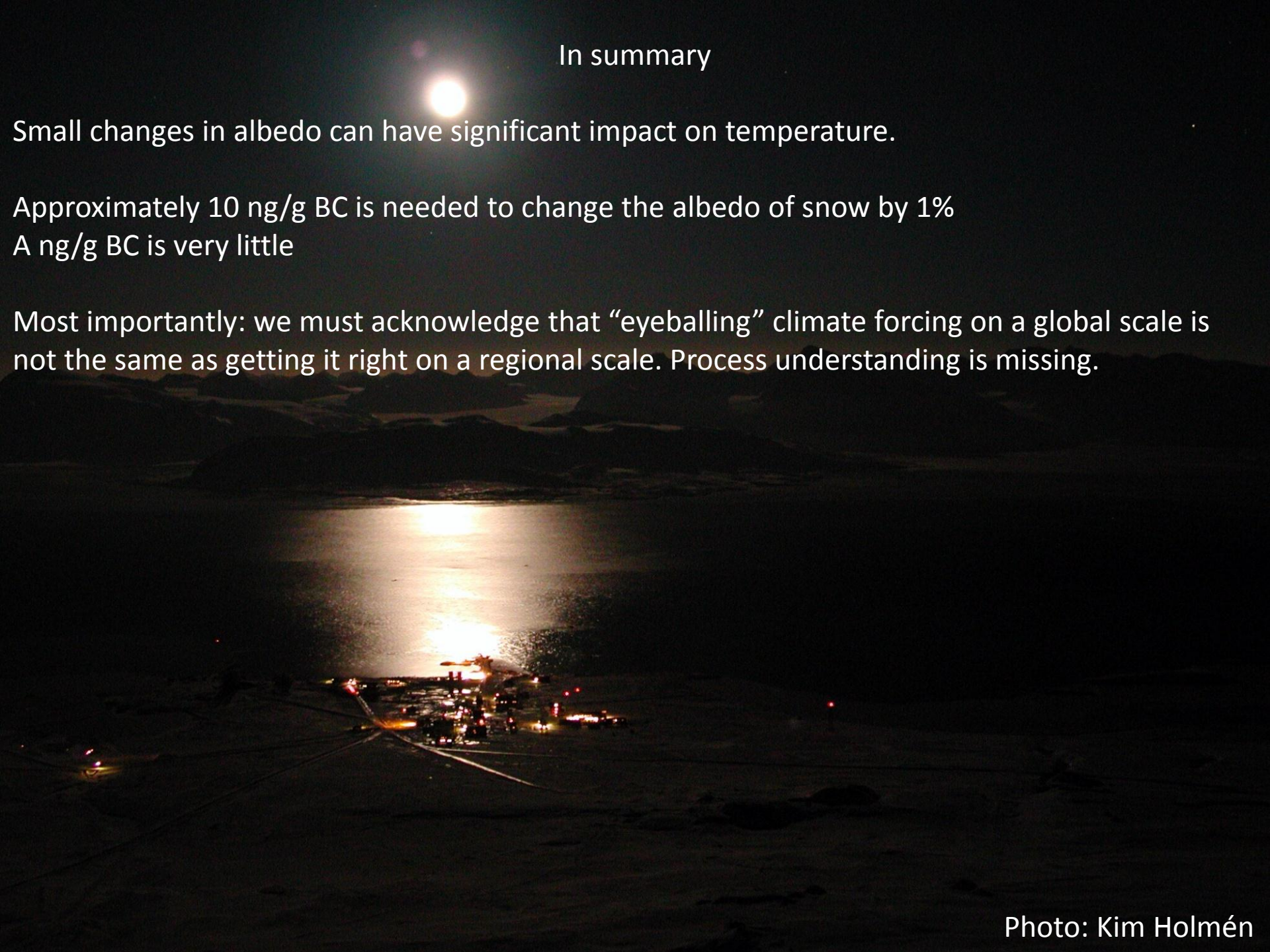
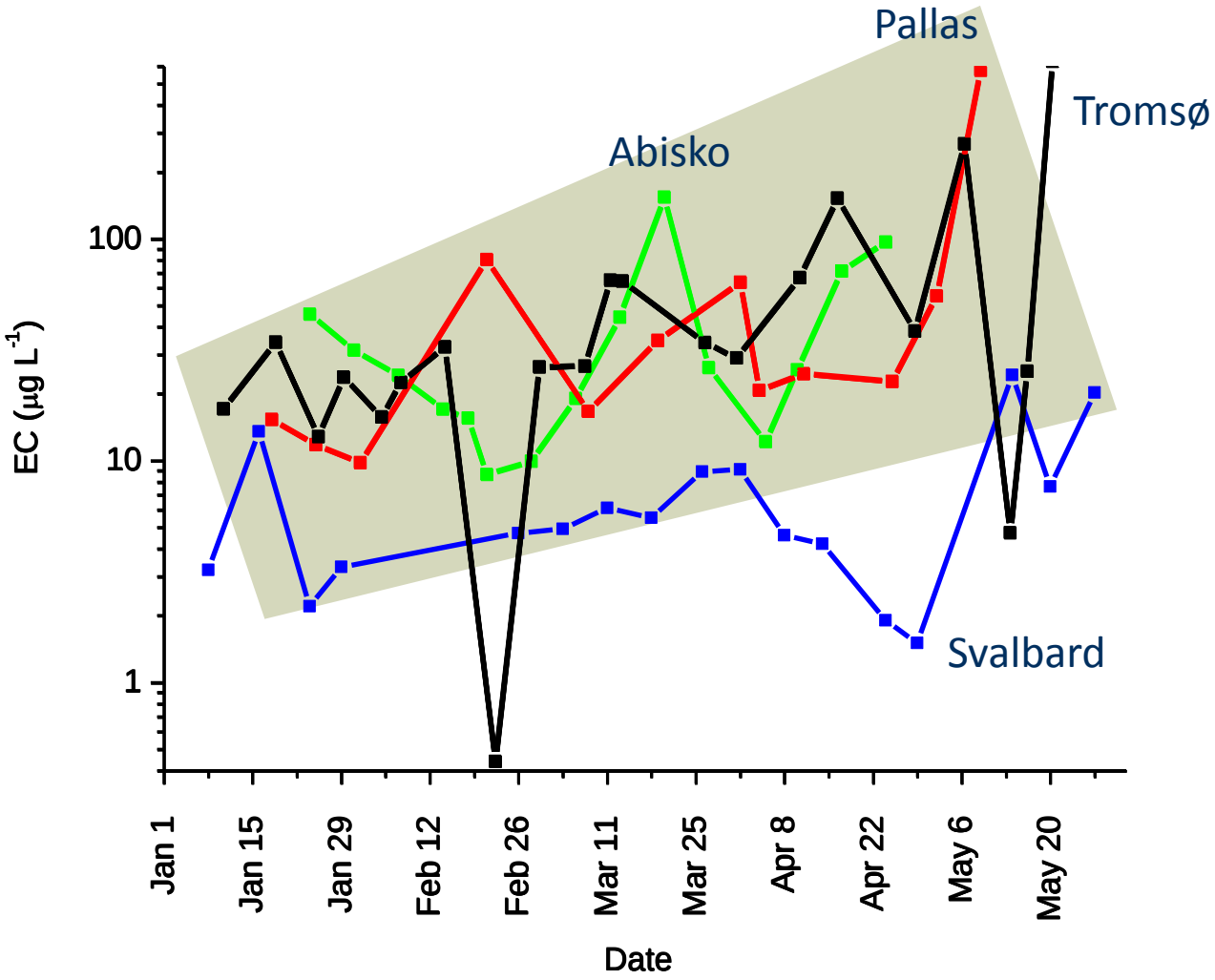


Photo: Kim Holmén


Pallas
Tromsø
Abisko
Svalbard
EC (µg L-1)
100
10
1
Jan 1
Jan 15
Jan 29
Feb 12
Feb 26
Mar 11
Mar 25
Apr 8
Apr 22
May 6
May 20
Date