

SLCF and the Arctic

Science update and preliminary results from recent modeling assessing black carbon effects on the Arctic from different regions and different sources

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Uio/CICERO



**UNIVERSITY
OF OSLO**

Geneva 13. September 2010

CICERO

Senter for klimaforskning

Center for International Climate and Environmental Research – Oslo

www.cicero.uio.no

Activities under the AMAP expert group

- Focus on Black Carbon aerosols
- Modelling experiments to quantify impacts in terms of radiative forcing from emissions in different regions and sectors
- Batch A: 25 combinations of regions and sectors have been identified

Status:

- Two models have performed the simulations
 - CESM (NCAR Earth system model) at Univ. of Michigan (Mark Flanner)
 - Oslo CTM2 at University of Oslo/CICERO (Karianne Ødemark and Terje Berntsen)
- Preliminary analysis of direct radiative forcing have been performed
- Analysis of radiative forcing due to deposition on snow and ice is not yet available
- A third model – GISS model (Koch/Unger) will do the simulations

Batch A

Regions/ Sectors	US	Canada	Russia	Scandinavia	ROW
Domestic	M,O	M,O	M,O	M,O	M
Transport	M,O	M,O	M,O	M,O	M
Agriculture	M,O	M,O	M,O	M,O	M
Industry/ power/waste	M,O	M,O	M,O	M,O	M
Grass+forest	M,O	M,O	M,O	M,O	M

Model: NCAR Community Earth System Model 1.0, resolution:
1.9 x 2.5 degrees

Configuration: Active atmosphere, land, sea-ice, and slab
ocean model (active ocean/ice needed for sea-ice aerosol
forcing). Initial conditions: Y2000 climate.

Aerosols: Bulk aerosol model (*Rasch et al, 2001*), no indirect
cloud forcing in these runs

Sea-ice aerosol effect: *Briegleb and Light (2007)*

Snow aerosol effect: SNICAR (*Flanner et al, 2007, 2009*)

Model length: 14 month run (2 month spinup + one full year) for
emissions from each region and sector

Emissions: *Lamarque et al, ACP, 2010*

Instantaneous direct radiative forcing calculated within
atmospheric, snow, and sea-ice components

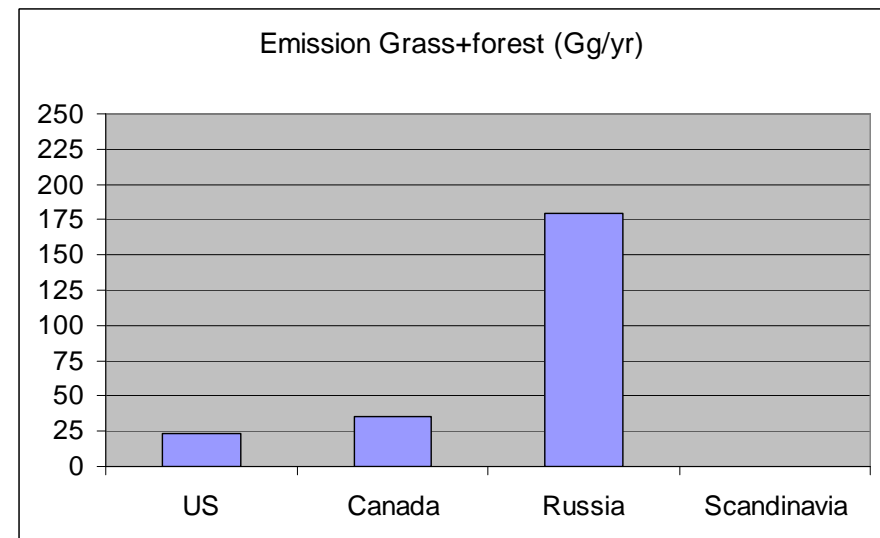
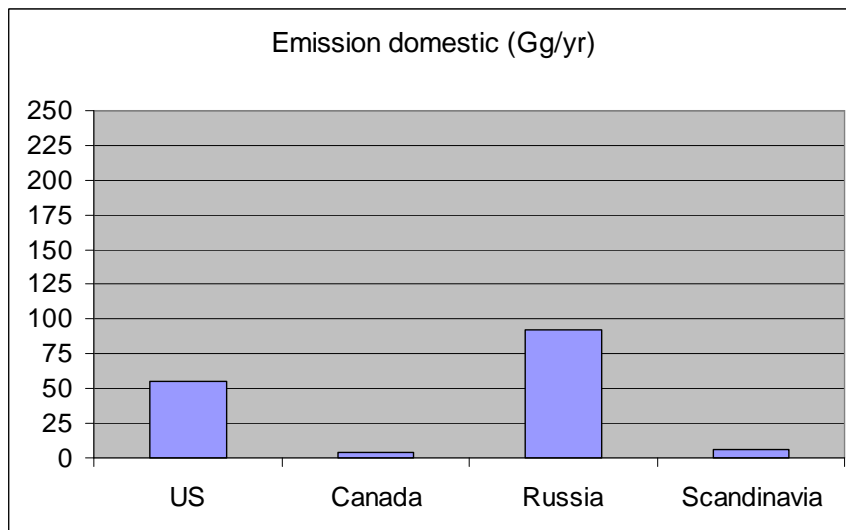
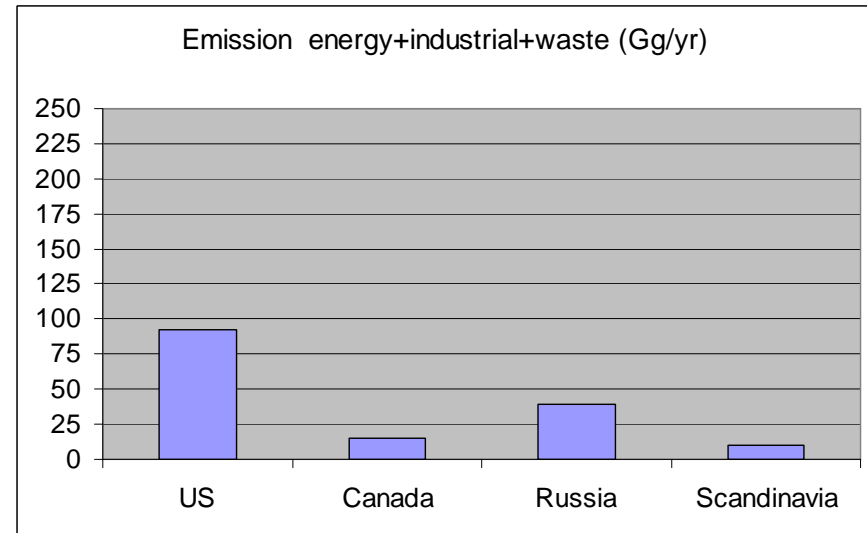
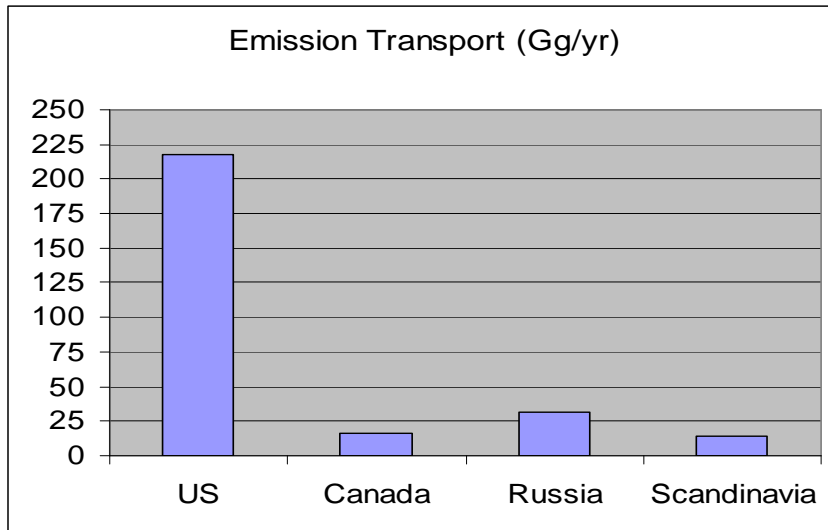
Models/setup UiO/CICERO

- Oslo CTM2, offline global chemistry transport model,
- Resolution: T42 (2.8°x2.8°), 40 vertical layers below 10 hPa
- Aerosols: Bulk scheme with modified aging times based on more detailed microphysical models (M7, Vignati et al., JGR)
- Radiative forcing: Derived from burden changes calculated by the Oslo CTM2 and normalized RF fields

$$nRF(BC_column, lat, long, month)$$

- Emissions: Lamarque et al, 2010
- BC in snow (land and sea ice). Simple snow-column budget module

Emissions of BC (Gg/yr) from sectors and regions



Ranking of sources (regions and sectors) contribution to RF 60°-90°N

Univ. of Michigan

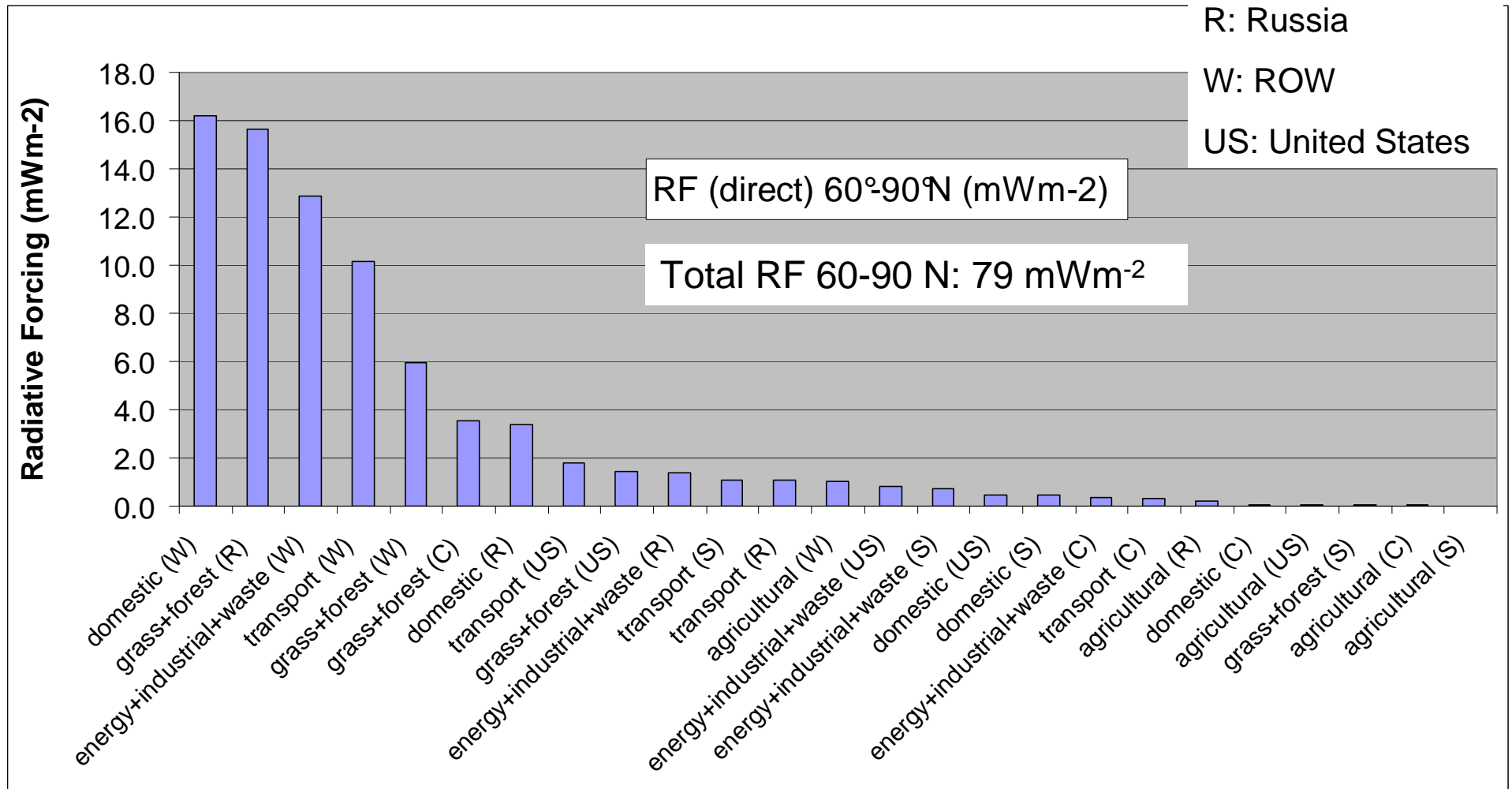
C: Canada

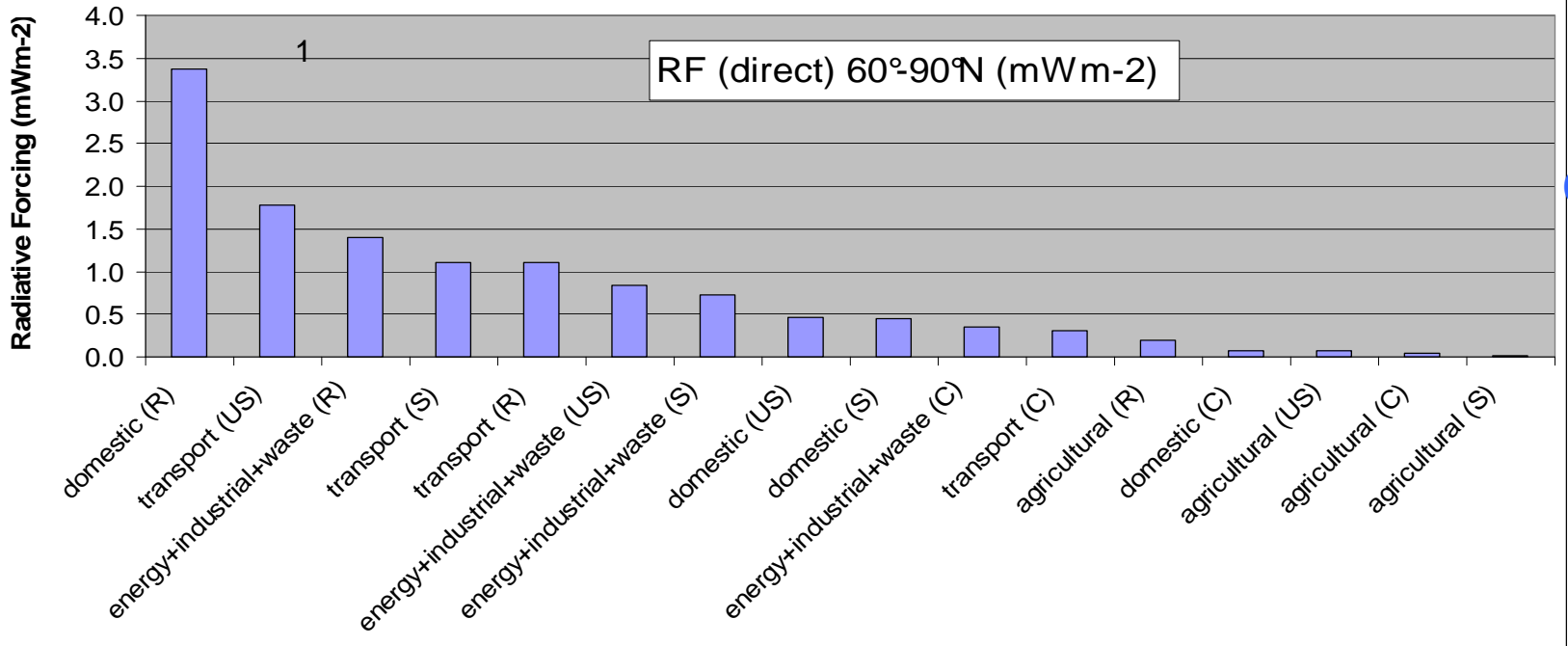
S: Scandinavia

R: Russia

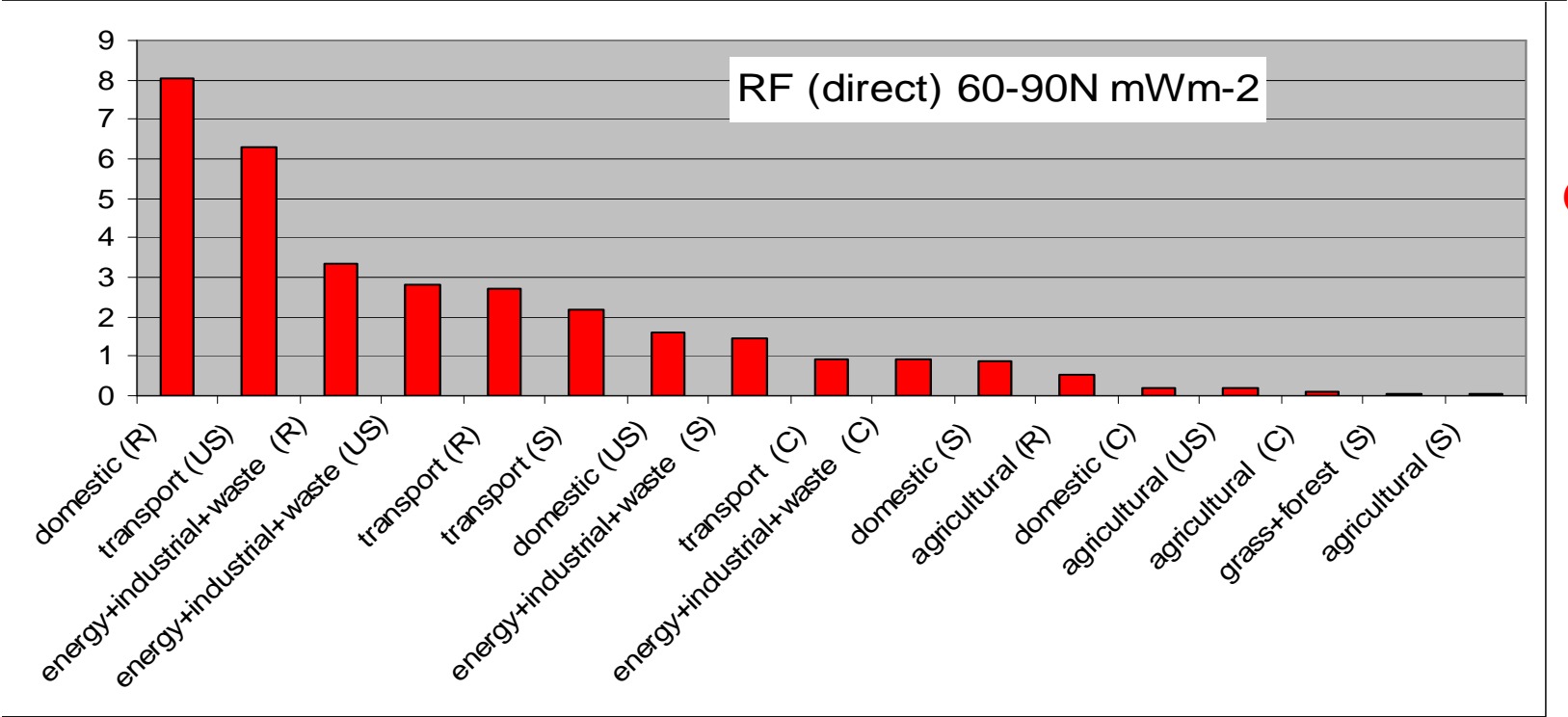
W: ROW

US: United States

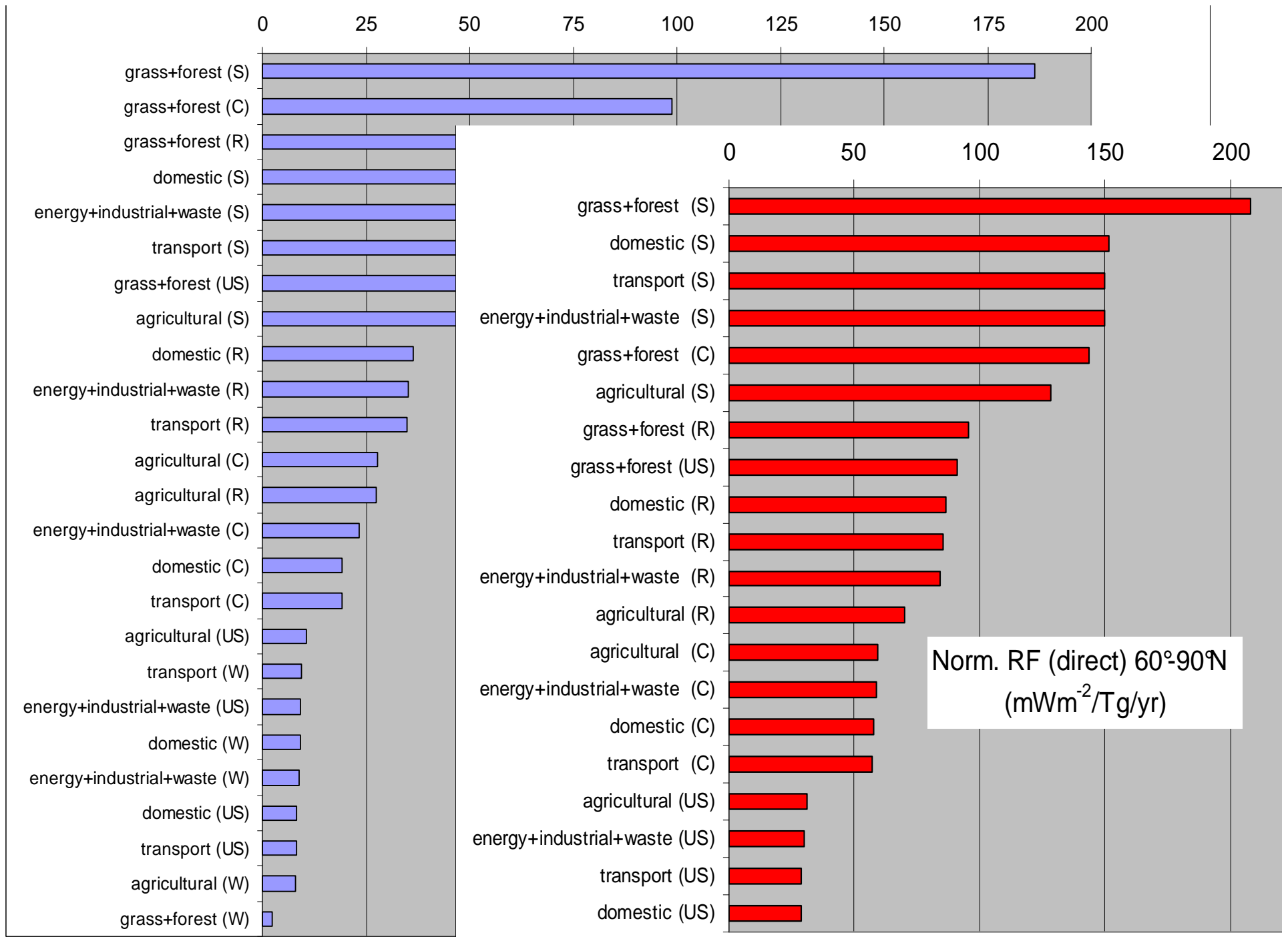


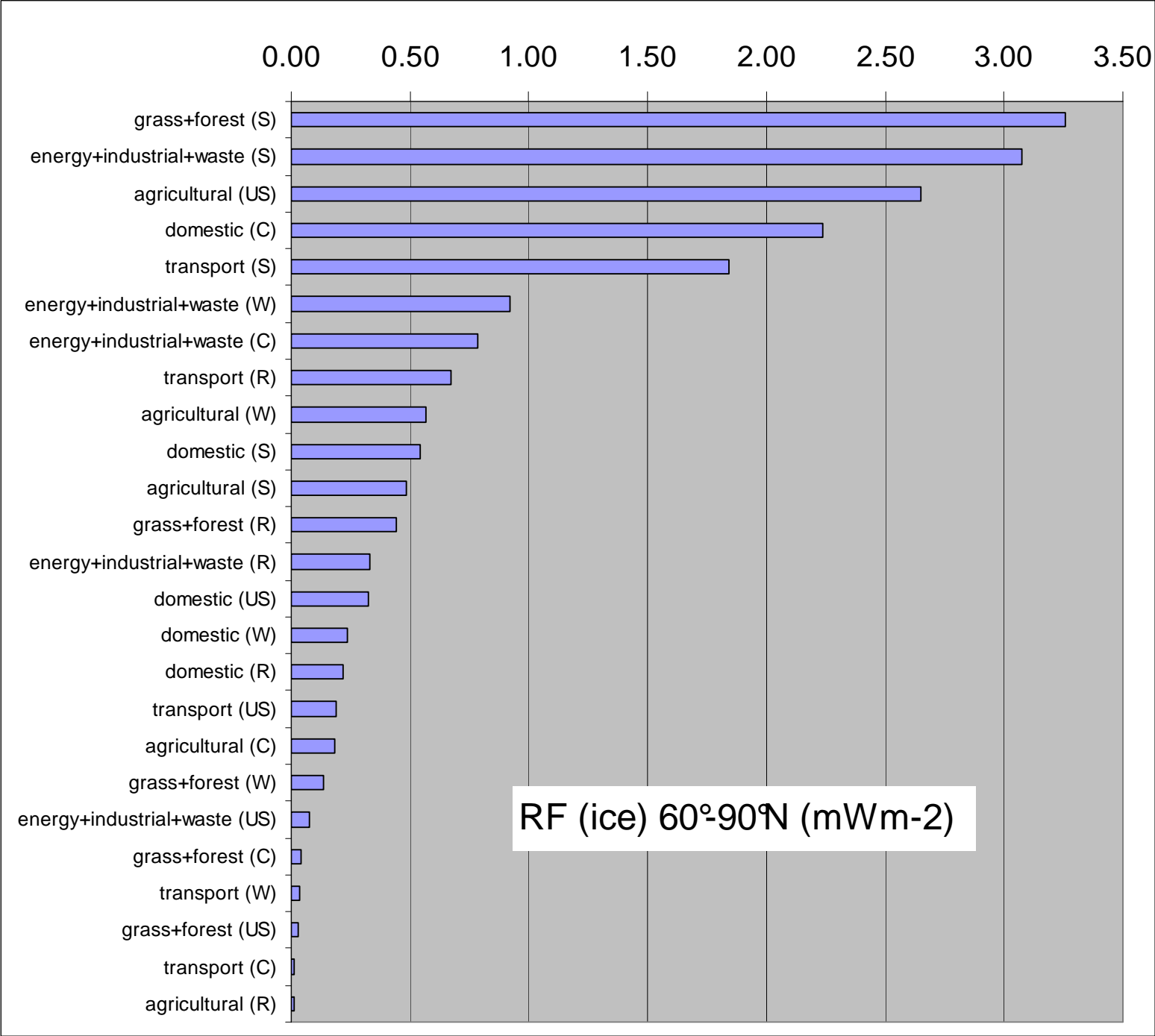


CESM (UM)

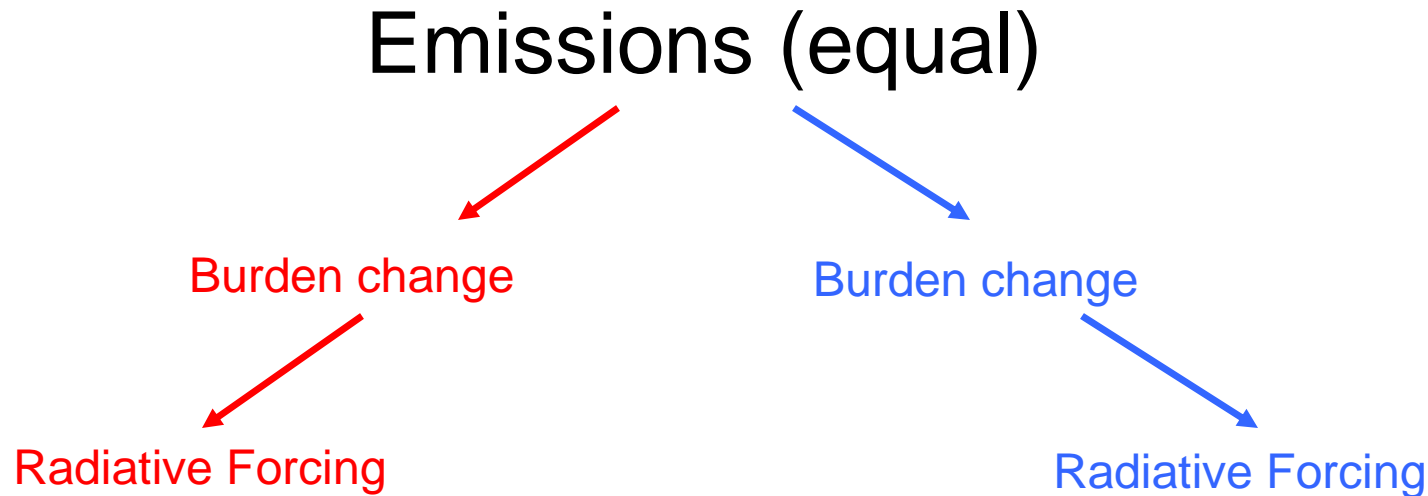


Oslo CTM2



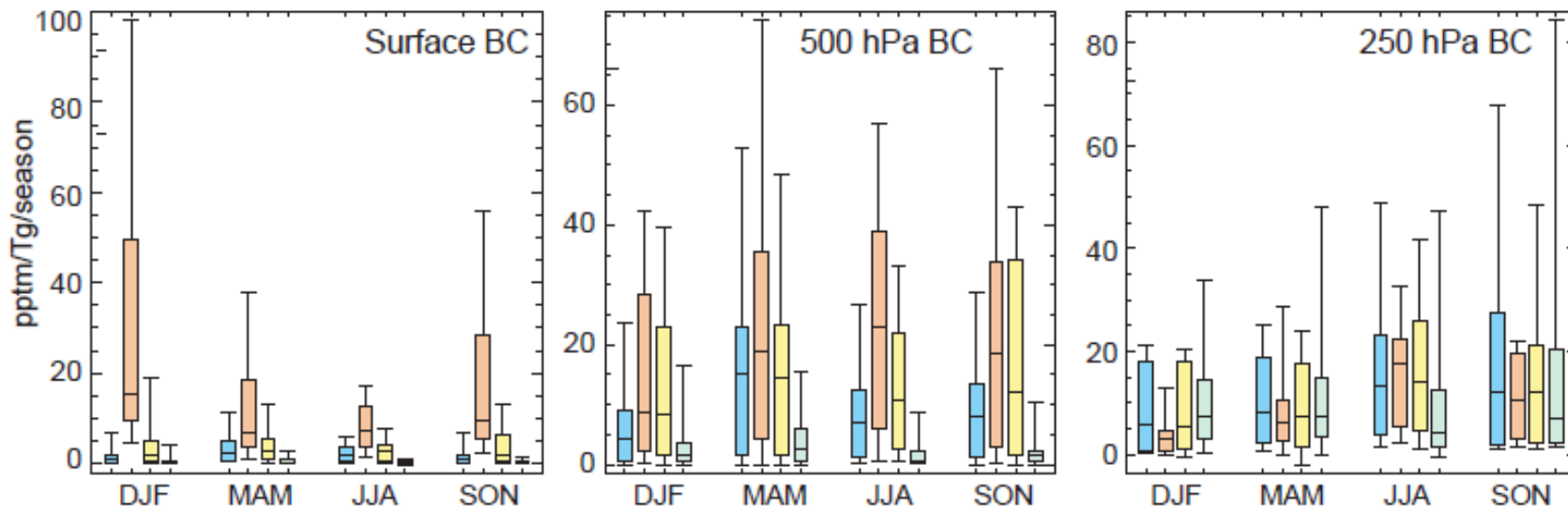


Why do the models differ?



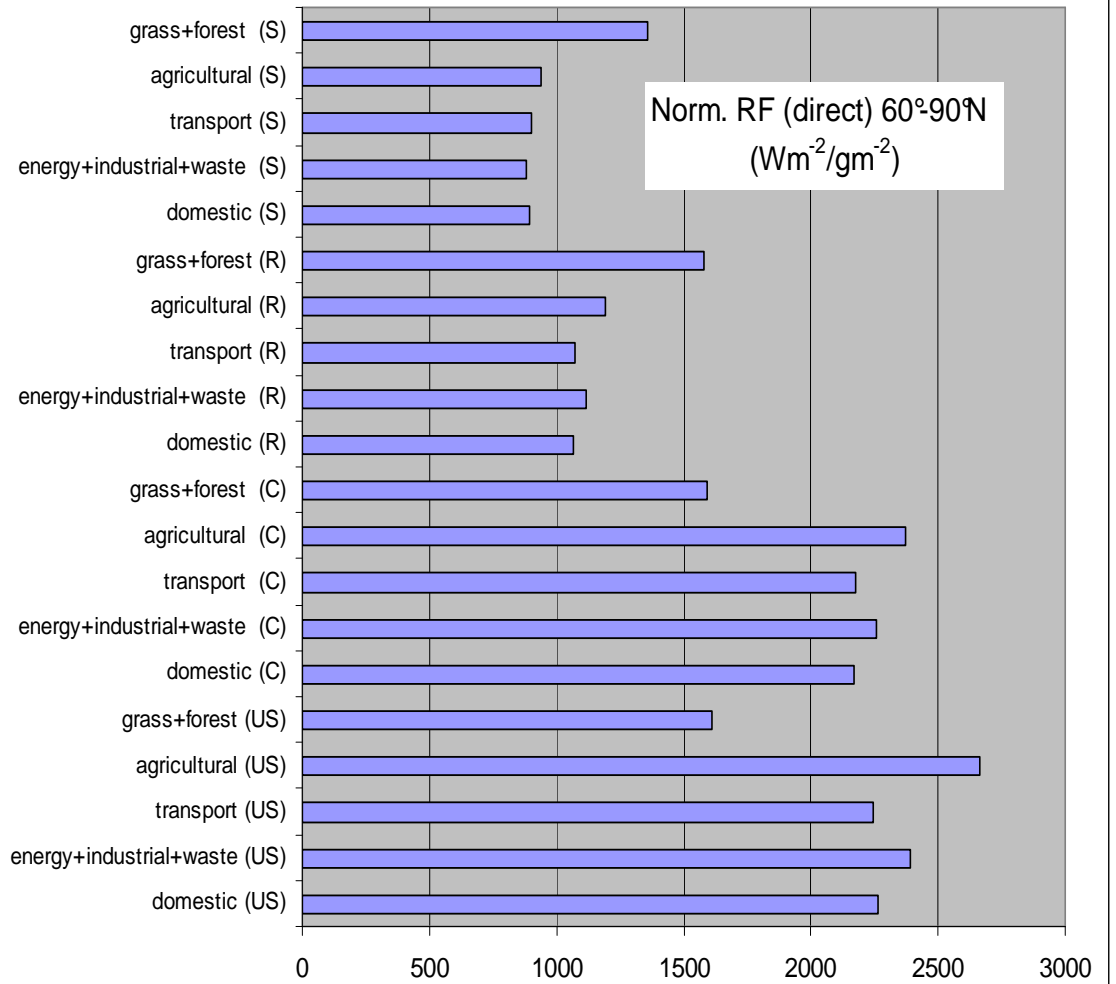
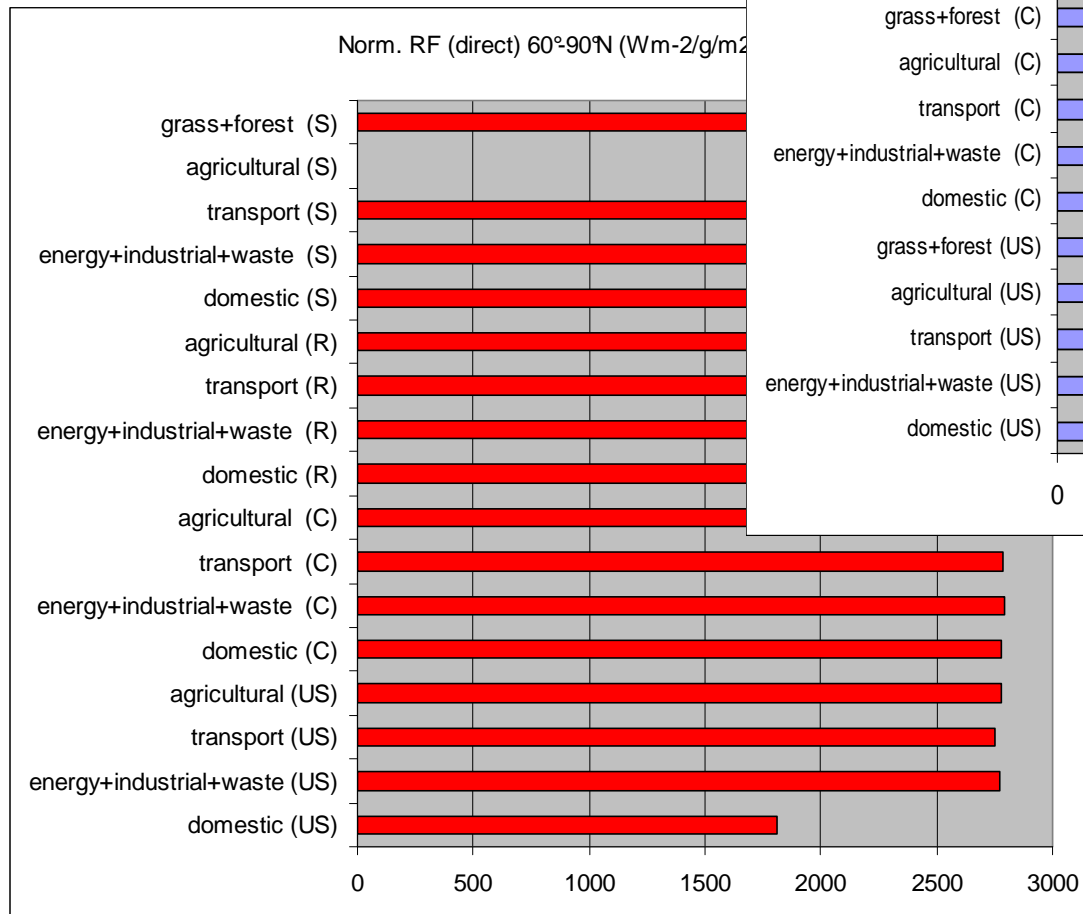
- Burden Change:
 - Atmospheric transport and mixing
 - "Aging" (Conversion from hydrophobic to hydrophilic form)
 - Deposition
- Radiative forcing
 - Optical properties
 - Location of BC relative to clouds
 - Surface albedo

Source region potential



Shindell et al., ACP, 2008

RF per unit burden change 60-90 N



C: Canada

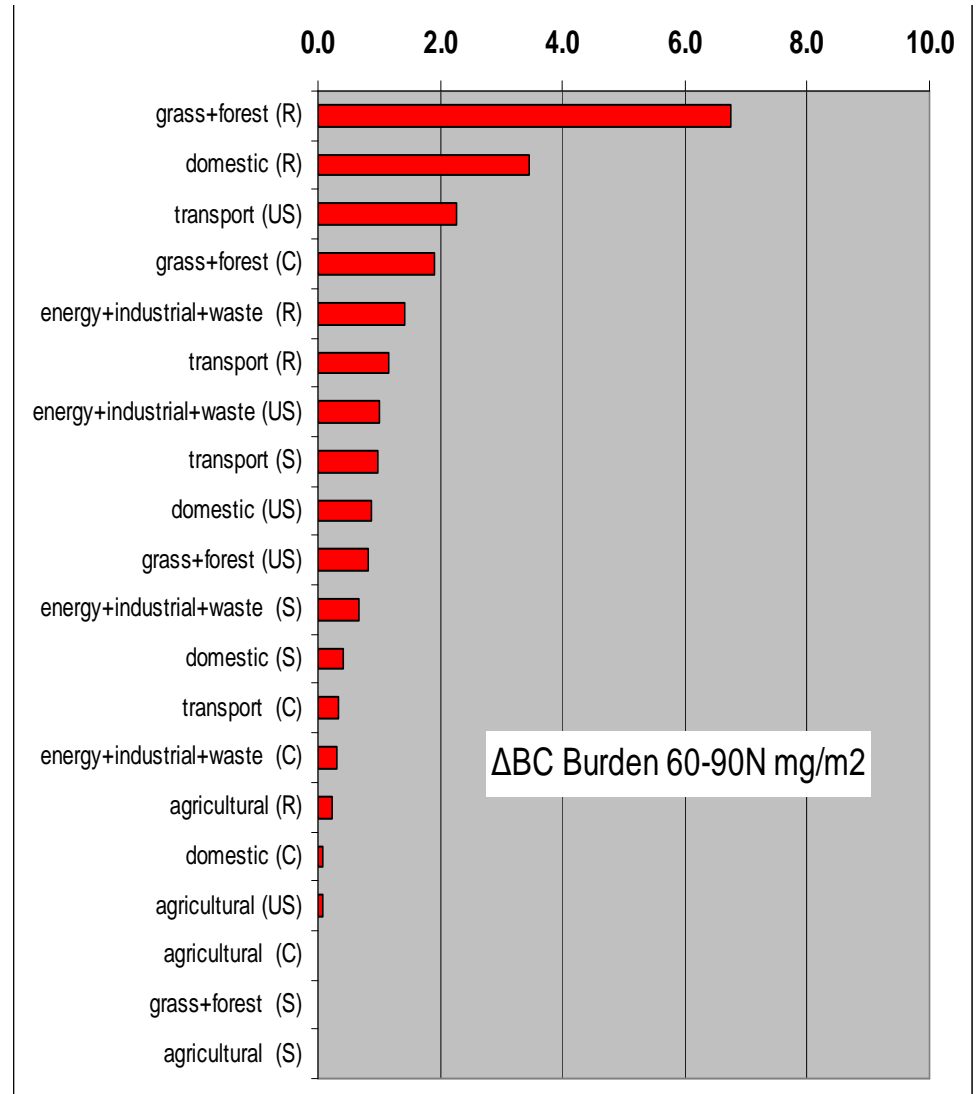
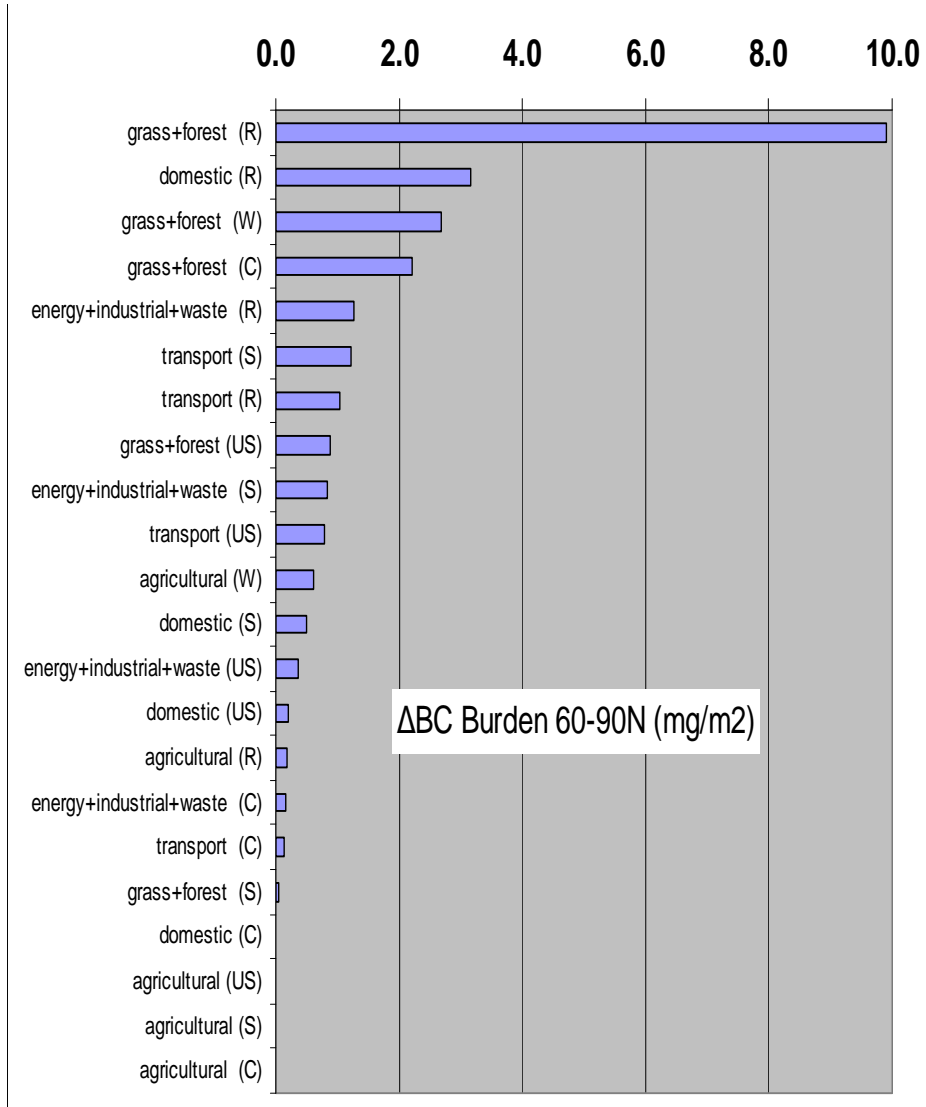
S: Scandinavia

R: Russia

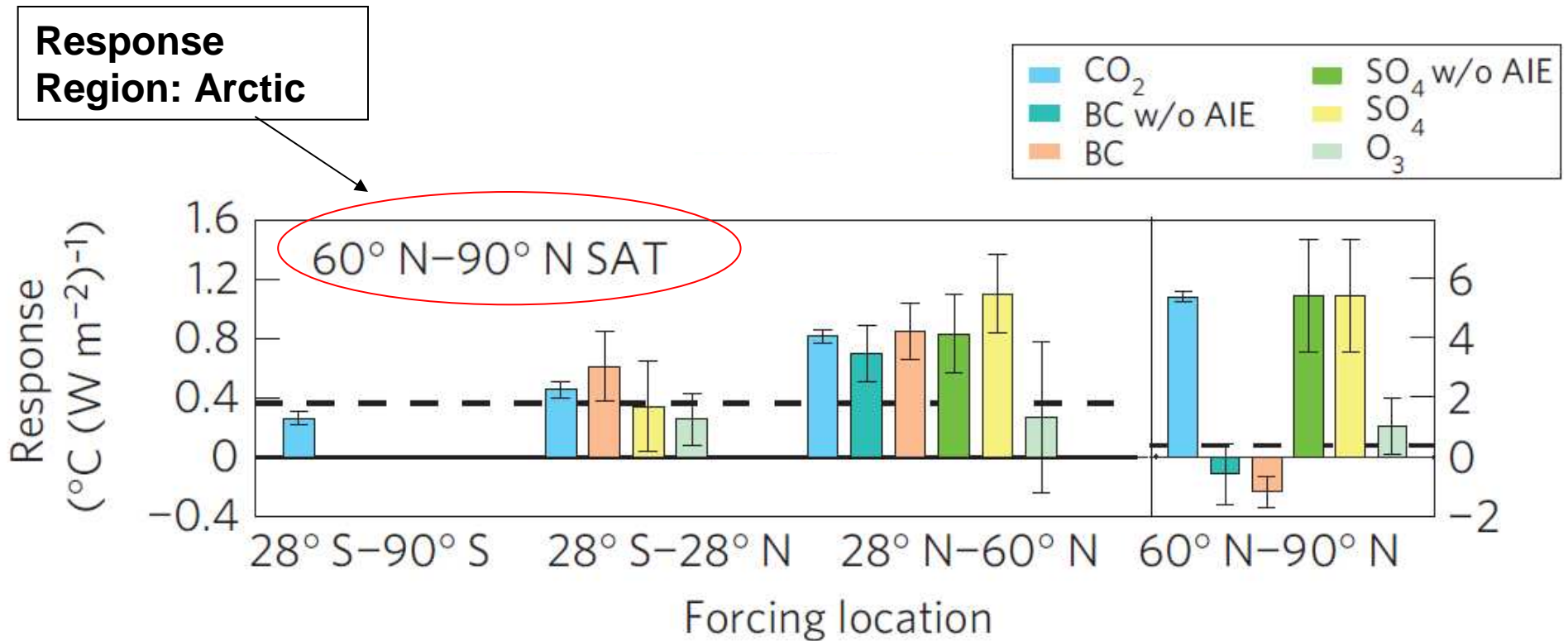
W: ROW

US: United States

Change in BC burden 60-90N



Does it matter where the forcing is located?



Shindell & Faluvegi, Nature Geoscience, 2009.

BC microphysical effects on clouds

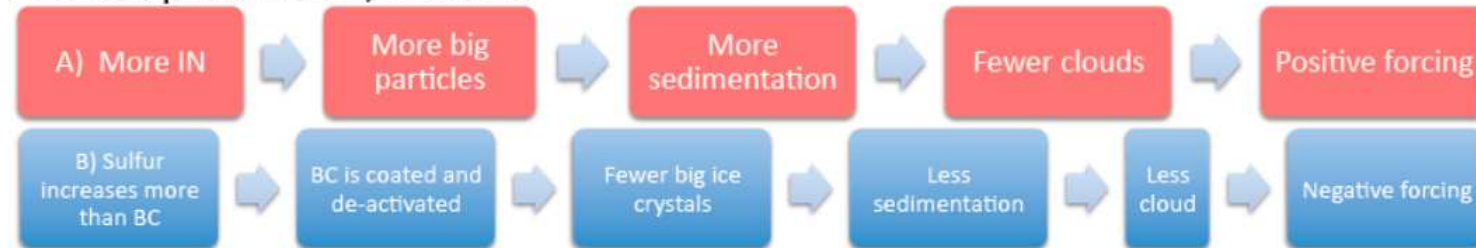
Add BC to:

1. Warm clouds, 2 mechanisms:



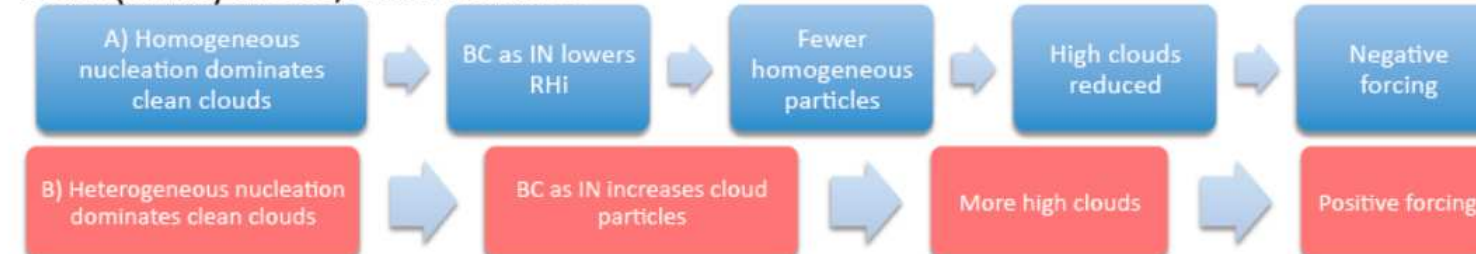
B tendency for pure BC; A for mixed BC/OC (Chen et al., 2010; Bauer et al., 2010; Jacobson 2010)

2. Mixed-phase clouds, 2 factors:



A dominates, Lohmann and Hoose (2009), +0.12 to +0.2 Wm⁻²

3. Ice (cirrus) clouds, 2 mechanisms:



A Penner et al. (2009) -0.5 Wm⁻²

B Liu et al. (2009) +0.3 to +0.7 Wm⁻²

Figure 5.1 Summary graphic of BC indirect effects on clouds.

Bond et al., in prep.

Preliminary conclusions

- Most of "Batch A" simulations have been carried out by two models – some diagnostics pending (most important RF due to BC on snow).
- Contribution to direct RF north of 60°N have been analysed
- Ranking of sources largely robust between the models, absolute levels approx. a factor of 2 different.
- Emissions from "Rest of the World" and wildfires are most important for radiative forcing north of 60°N
- Apart from that, Domestic (Russia) and Transport (US) are the most important sources
- In terms of RF per unit of emissions, Scandinavian sources are most effective
- Potentially important forcing mechanism and regional climate feedbacks are NOT included in this analysis

Important factors towards identification of regions and sectors for cost-effective mitigation of Black Carbon aerosols

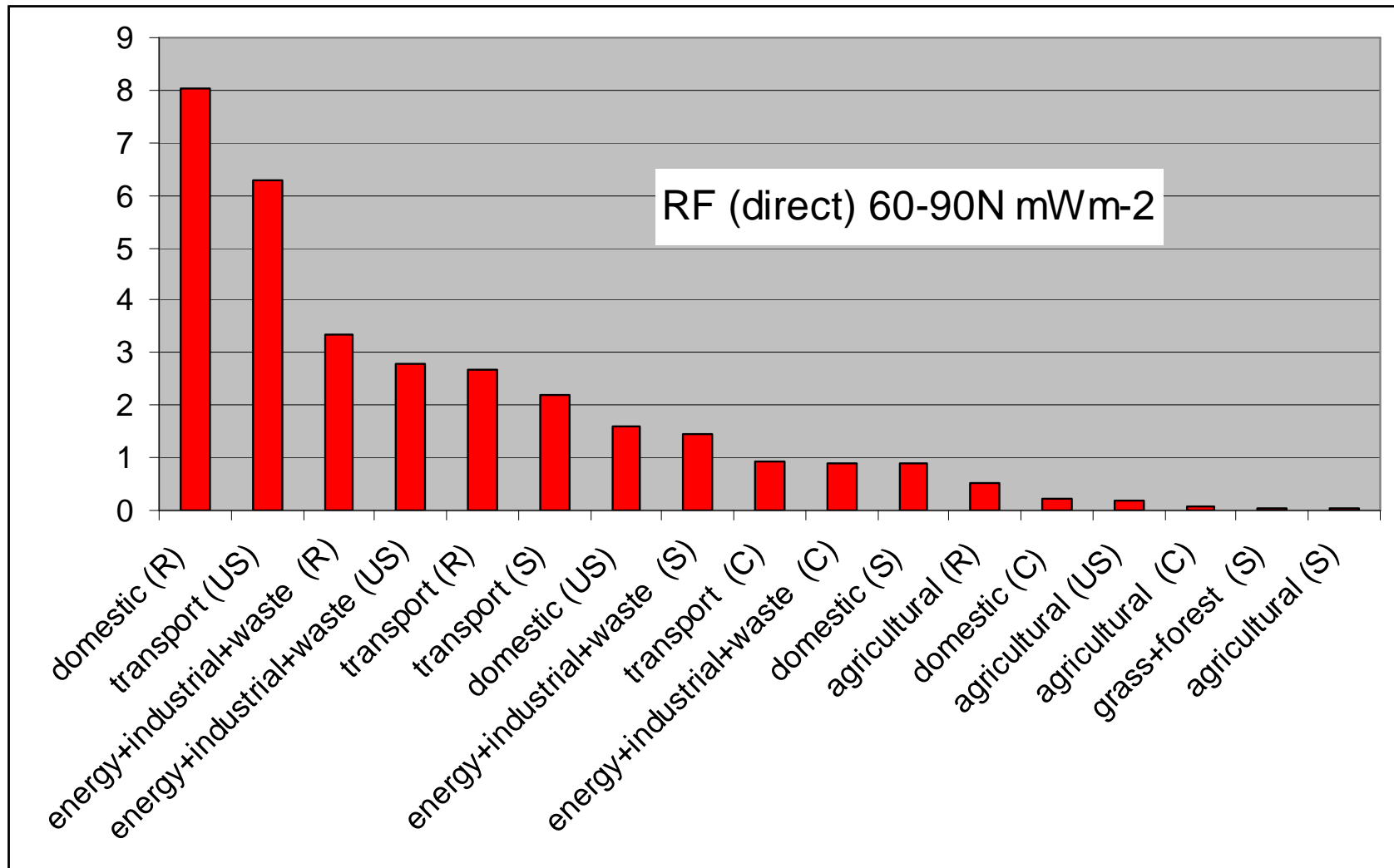
- Absolute level of impact (here Radiative Forcing)
- Impact normalized to emission (e.g. $\text{Wm}^{-2}/\text{Tg}(\text{yr})^{-1}$)

Other factors not discussed here:

- Changes in co-emitted species
- Mitigation costs
- Feasibility (Technologically and politically)

Ranking of sources (ROW and grass+forest removed) contribution to RF 60°-90°N.

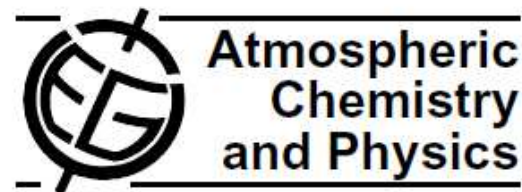
Univ. of Oslo



Other activities on understanding BC impacts on the climate

- "Bounding BC" initiative (Bond, Fahey, Forster ++)
 - Focus on quantifications (with uncertainties) of the effects of all possible processes where BC interacts with climate. Draft due soon.
- BC activity under EMEP/CLRTAP
 - Focus country specific contribution to direct radiative forcing by BC aerosols
 - Dedicated model simulations with the EMEP model at met.no (M. Gauss ++) with input on forcing efficiencies from CICERO (G. Myhre) → input to the GAINS model at IIASA
- UNEP assessment of BC

Atmos. Chem. Phys., 10, 7017–7039, 2010
www.atmos-chem-phys.net/10/7017/2010/
doi:10.5194/acp-10-7017-2010
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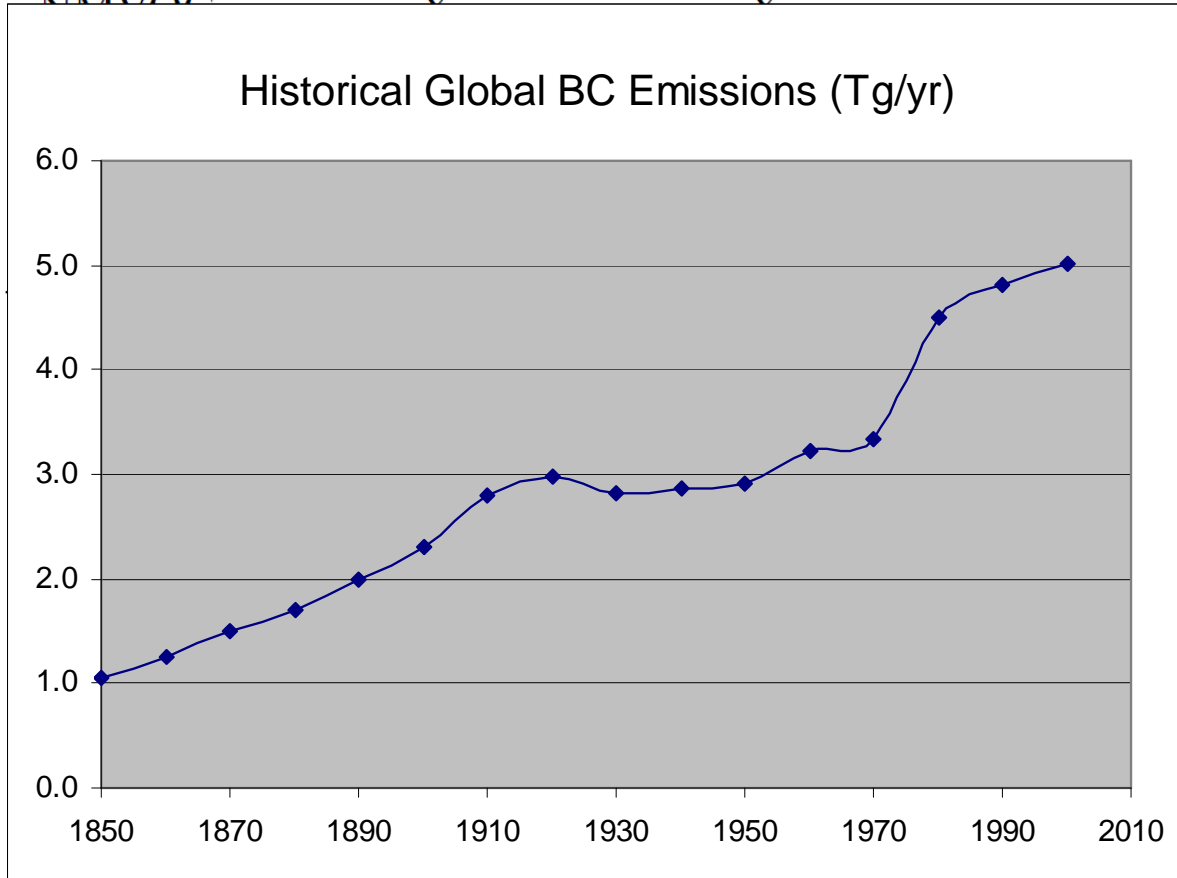


Historical (1850–2000) gridded anthropogenic and biomass burning emissions of reactive gases and aerosols: methodology and application

J.-F. Lamarque¹, T. C. Bond², V. Eyring³, C. Granier^{4,5,6}, A. Heil⁷, Z. Klimont⁸, D. Lee⁹, C. Lioussé¹⁰, A. Mieville⁶, B. Owen⁹, M. G. Schultz⁷, D. Shindell¹¹, S. J. Smith¹², E. Stehfest¹³, J. Van Aardenne¹⁴, O. R. Cooper⁴, M. Kainuma¹⁵, N. Mahowald¹⁶, J. R. McConnell¹⁷, V. Naik¹⁸, K. Riahi⁸, and D. P. van Vuuren¹³

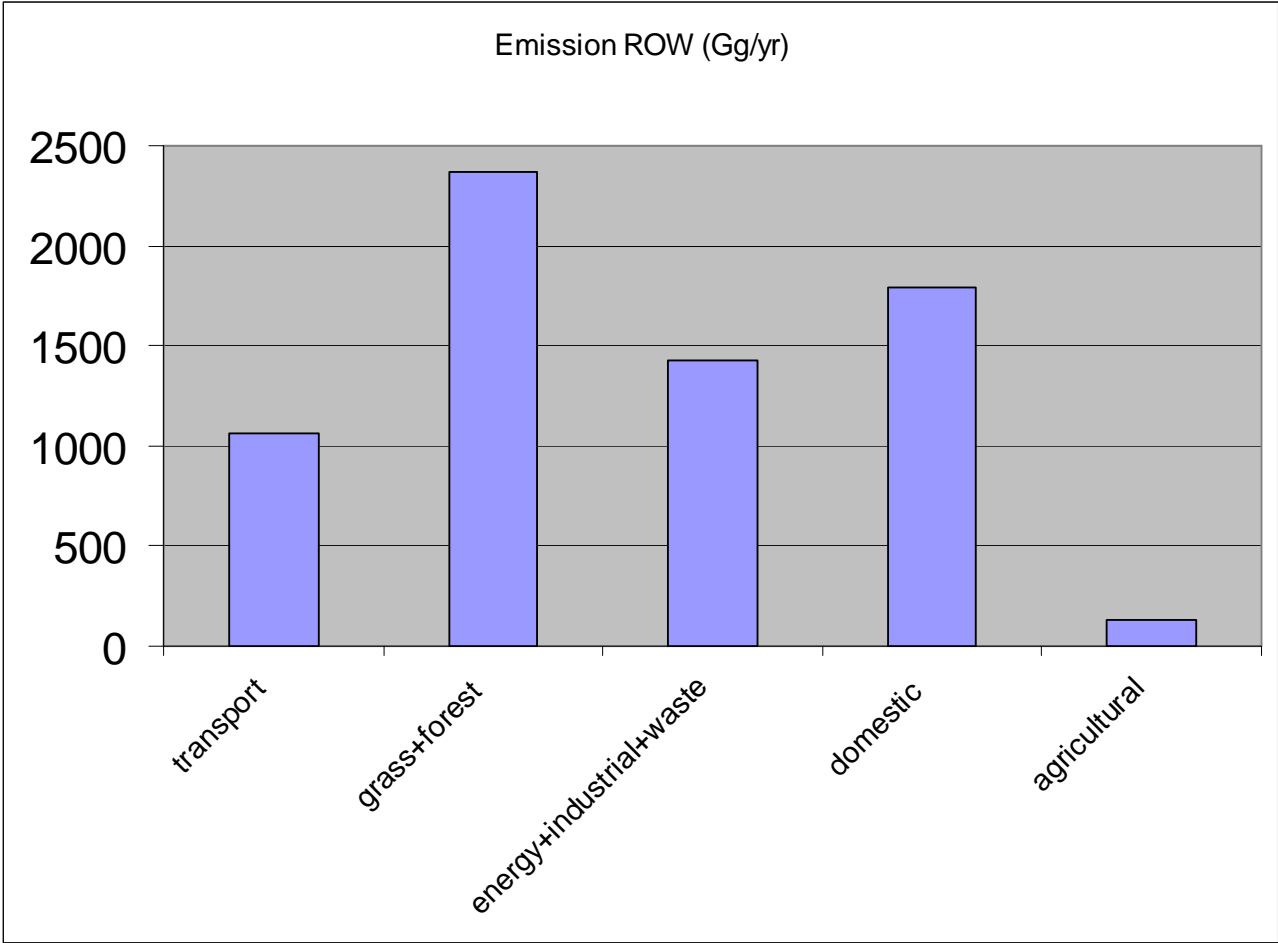
¹ CNRS, Météo-France, UMR 5175, Observatoire Midi-Pyrénées, Toulouse, France

	EDGAR-HYDE EDGAR	RETRO	Smith et al.	Bond et al.	Junker and Liousse
Species	1890–2000	1960–2000	1850–2000	1850–2000	1860–1997
CH ₄	X				
CO	X	X			
NO _x	X	X			
NMHC	X	X			



X	X
X	X

Emissions in "Rest of the World"



Climate impacts of soot aerosols in the Norwegian Earth System Model (NorESM)

Alf Kirkevåg, Trond Iversen,
Jens Boldingh Debernard, Øyvind Seland, Mats Bentsen,
Corinna Hoose, Jón Egill Kristjánsson,
Mark Flanner, Steve Ghan, Phil Rasch

Acknowledgement:

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Atmospheric Research,
NCAR
Pacific Northwest
National Laboratory,
PNNL



IPY-Oslo Science conference,
Lillestrøm, June 10'th 2010

Light-absorption by soot and mineral dust on snow and sea-ice is included in NorESM

In the land model (CLM4 from NCAR):

The SNow, ICe, and Aerosol Radiative (SNICAR) model (Flanner et al., 2007; 2009)

- grain-size dep. snow aging
- aerosol deposition (**BC**, **DU**)
- meltwater scavenging of aerosol
- look-up tables for optical parameters
- multilayer radiative transfer in the snow

In the sea-ice model (CICE4 from NCAR):

(Holland et al., 2010, draft in preparation)

- aerosol deposition (**BC**, **DU**)
- BC and DU impact on snow albedo through CICE's own radiation transfer module

Simulations - all fully coupled:

1. CTRL 68 years:

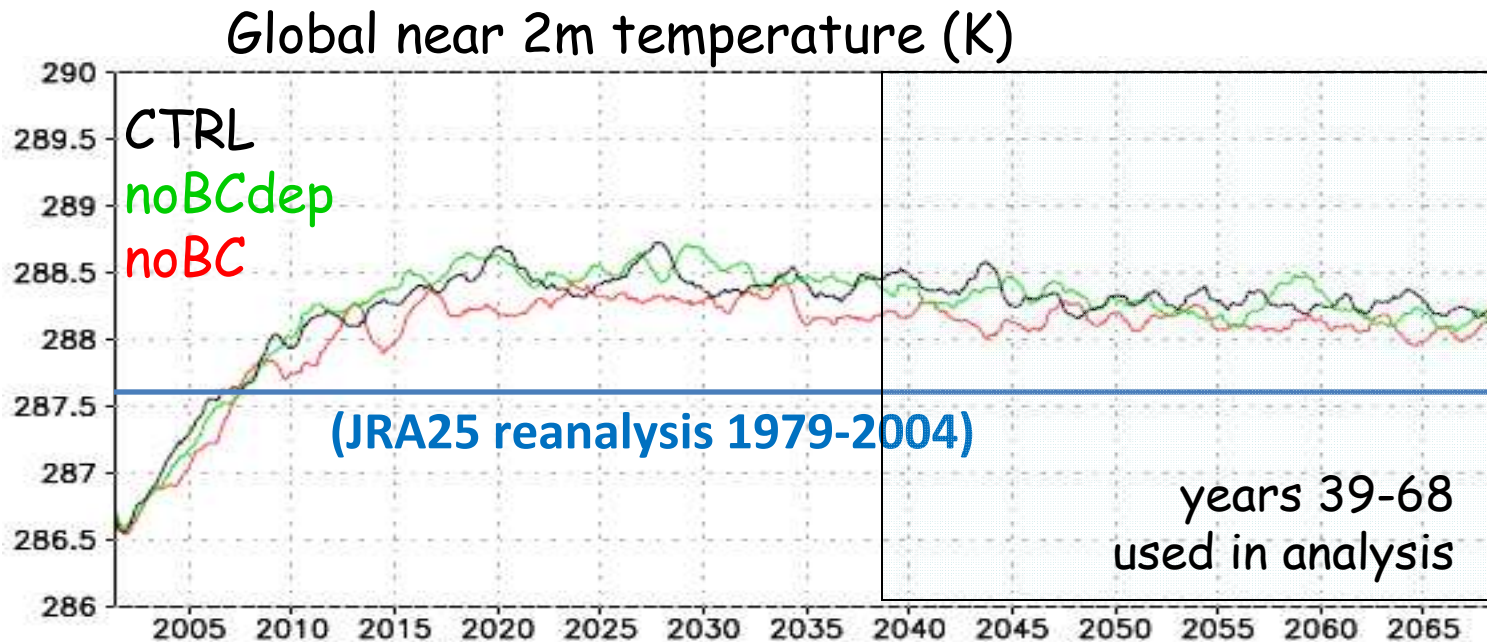
Year 2000 aerosol emissions and GHG concentrations

2. noBCdep 68 years:

As CTRL, but no effects of BC deposition on snow and sea-ice albedo

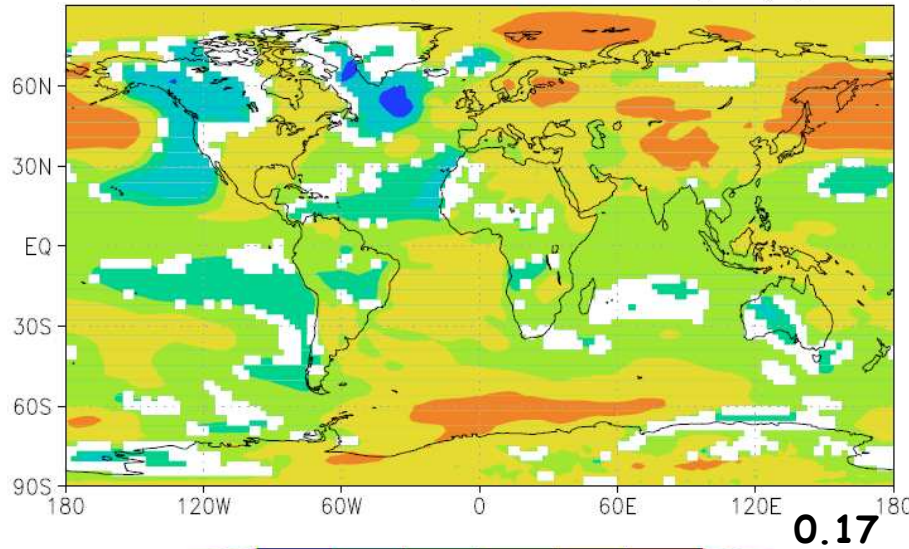
3. noBC 68 years:

As CTRL, but BC aerosols excluded (entirely)

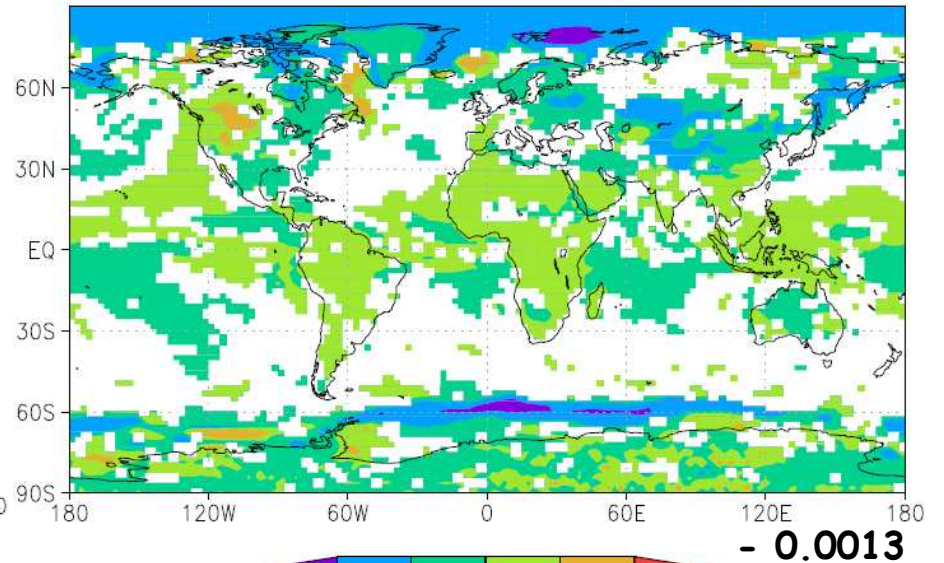


Response of all BC: CTRL - noBC

Temp. Increased air temperature at 2m height (°C)

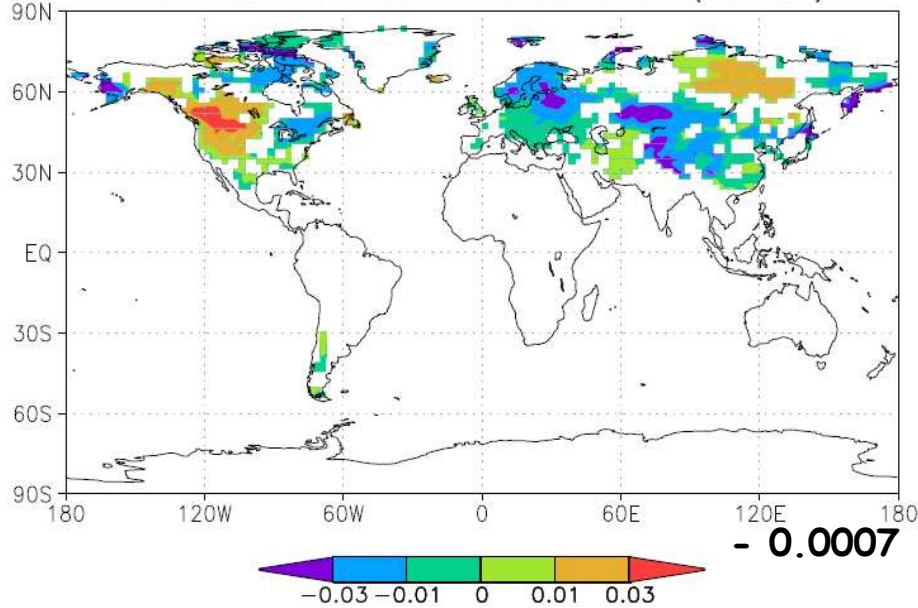


albedo Increased surface albedo (fraction)



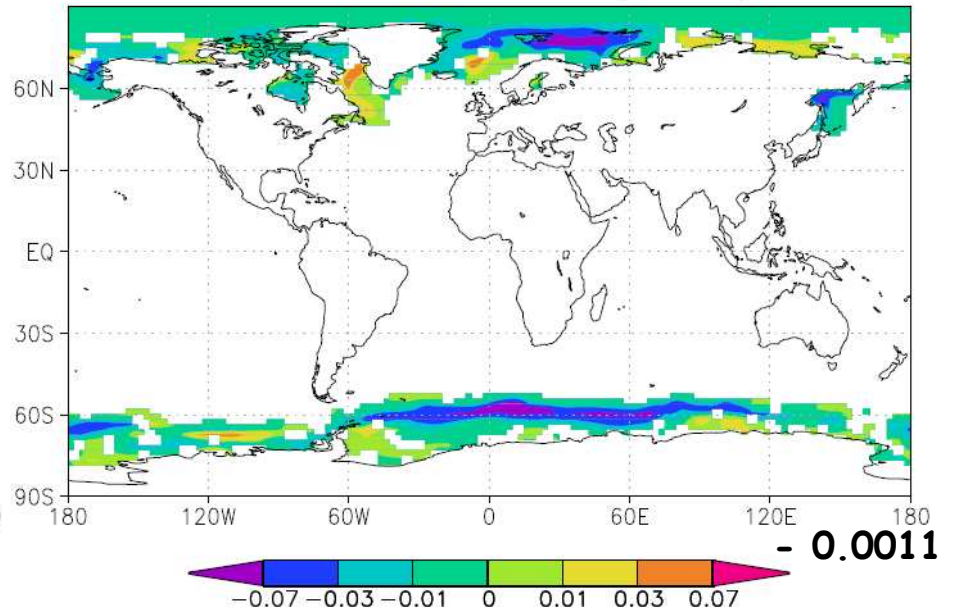
Snow cover

Increased land-surface snow-cover (fraction)



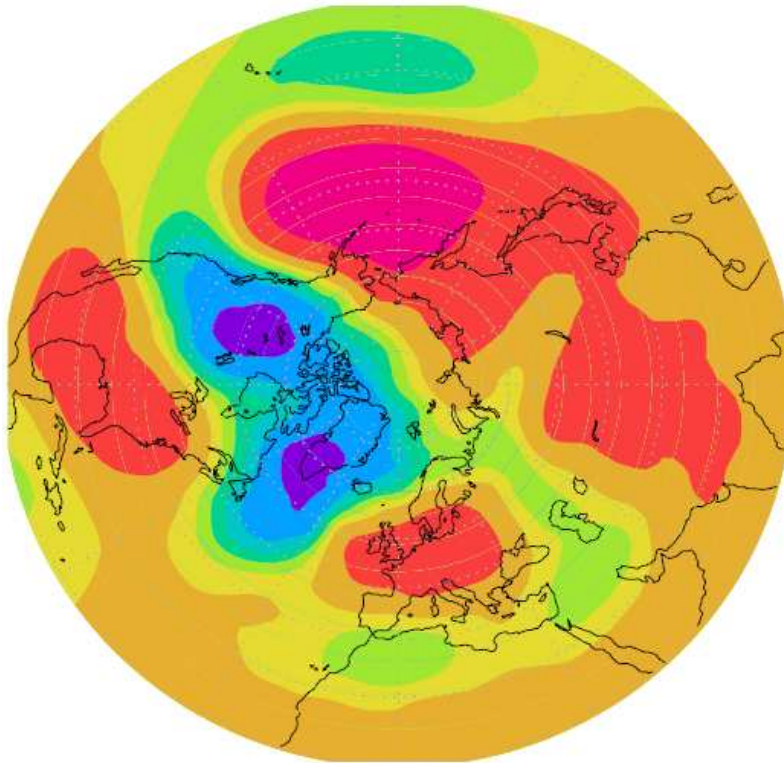
Sea-ice cover

Increased sea-ice cover (fraction)



Response: NH winter mid-tropospheric flow (500hPa)

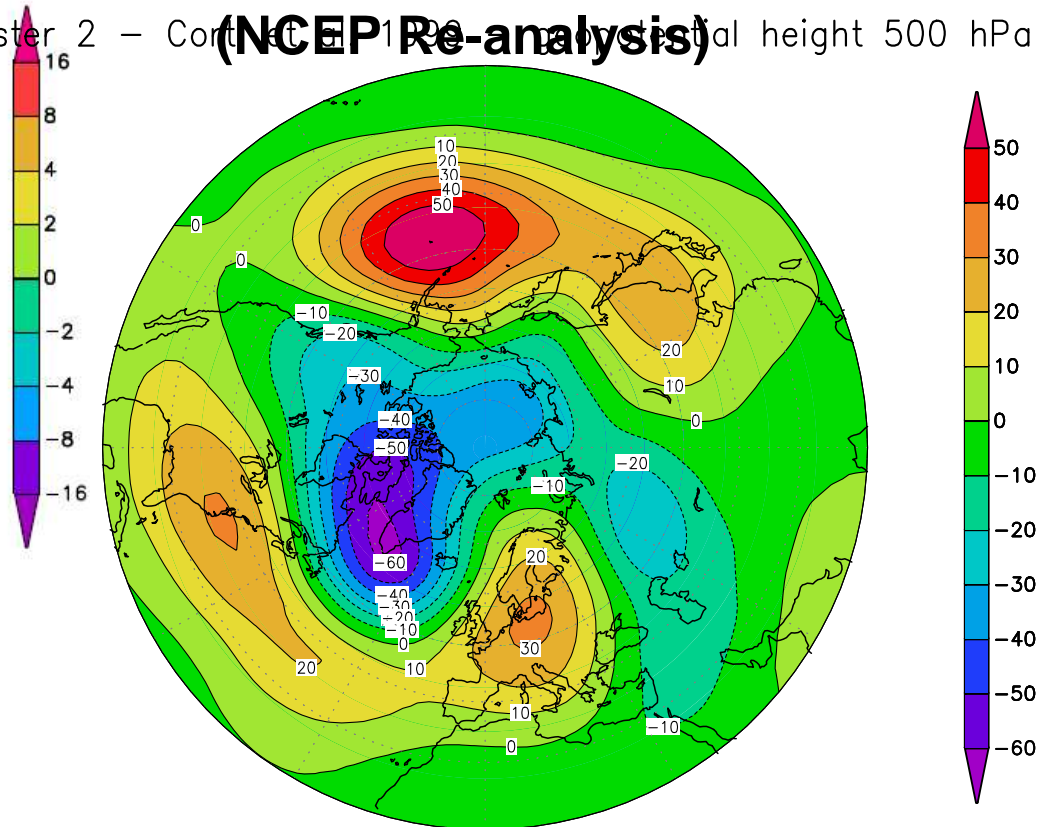
NorESM:
CTRL - noBC:
Response to all BC

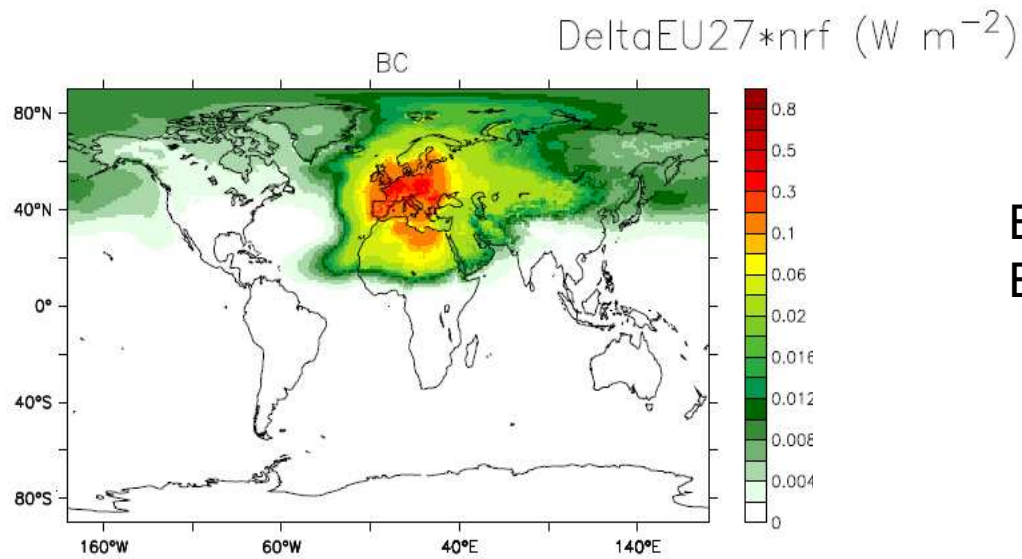


Reference: flow-regimes
from re-analysed data
(Corti et al, 1999; Nature)

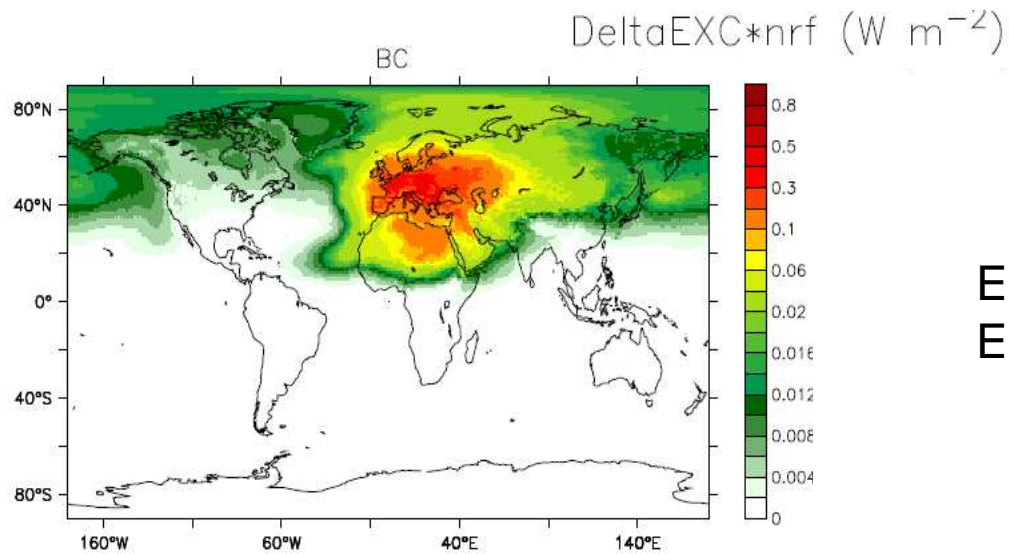
ClusterB
PNA-; NAO+
(INCEP Re-analysis)

Cluster 2 - Corti et al (1999) (INCEP Re-analysis) at 500 hPa





Emissions in all
EU-27 countries



Emissions in all
EMEP countries

Figure 4.2: Calculated RF due to BC and POC caused by emissions from EU27 countries (upper panels) and all EMEP countries (lower panels) (Wm^{-2}).

