Vertical profiles of aerosol radiative forcing - a comparison of AEROCOM phase 2 model submissions

AeroCom meeting, 12.09.2012
B. Samset, G. Myhre, AeroCom modellers

- **Attribution of modeled BC RF diversity due to vertical profile (being submitted)**
- **Sensitivity of vertical SO4 forcing efficiency profiles to relative humidity (in early stages)**

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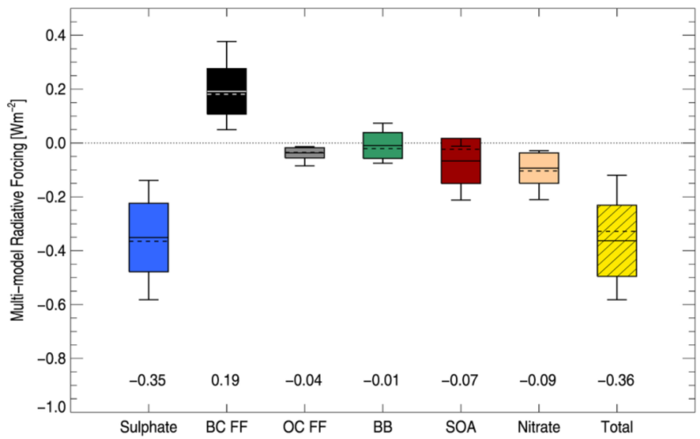
AeroCom: Comparing aerosol models, assessing modelling uncertainty

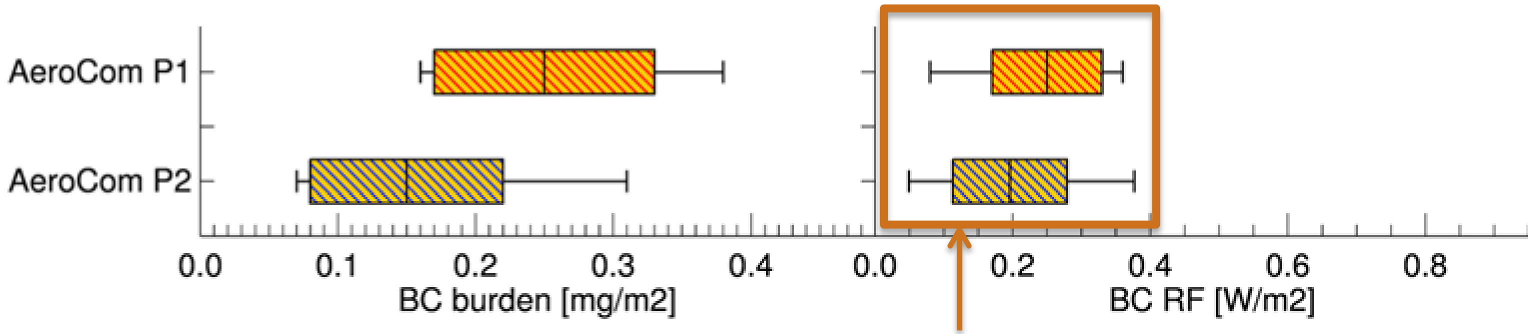
- Models run prescribed experiments (unified emissions, met. years)
- ~15 global models participating, GCMs and CTMs
- Two phases performed. For phase 1, see e.g. Schulz et al 2006, ACP
- Several phase 2 papers recently submitted

Radiative forcing from the direct aerosol effect:



Myhre et al, subm.

Black carbon model diversity in phases 1 and 2:



Samset et al, to be resubm.

What causes this diversity? Why hasn't it changed between phases 1 and 2?

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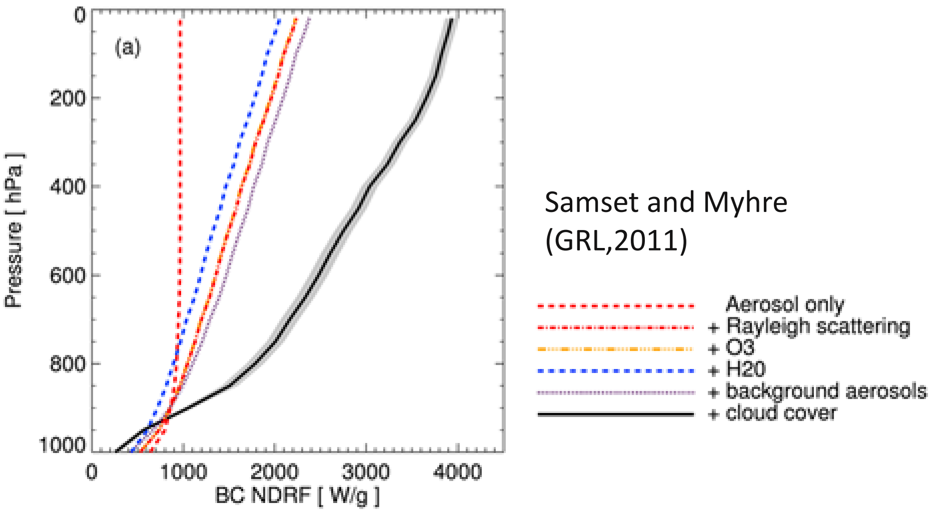
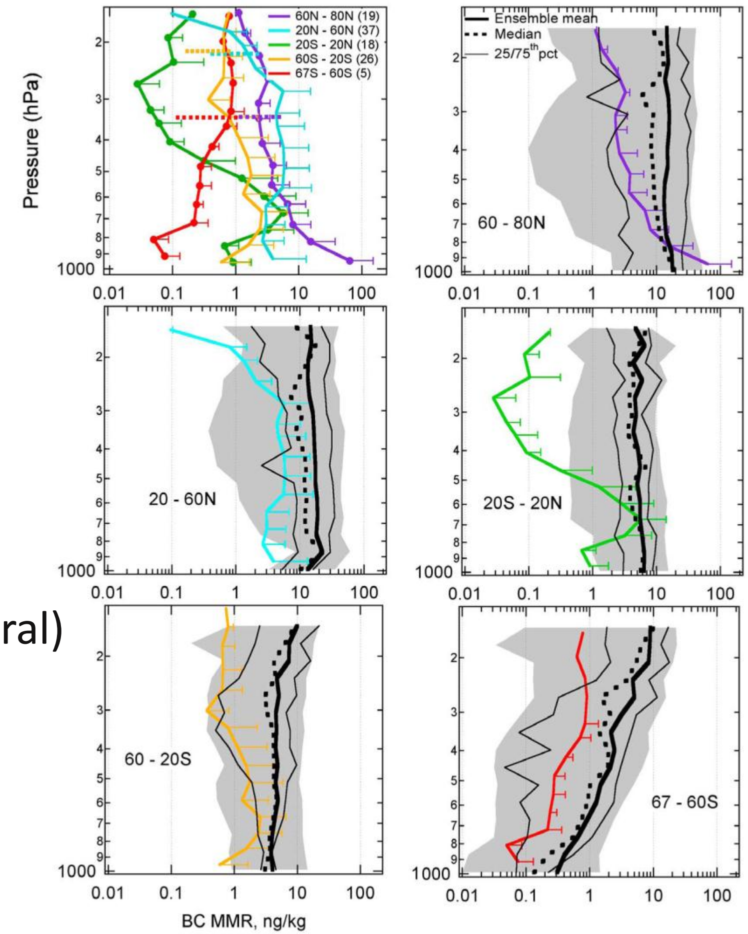
Black carbon forcing is affected by its vertical distribution – which is poorly constrained, both in models and observations



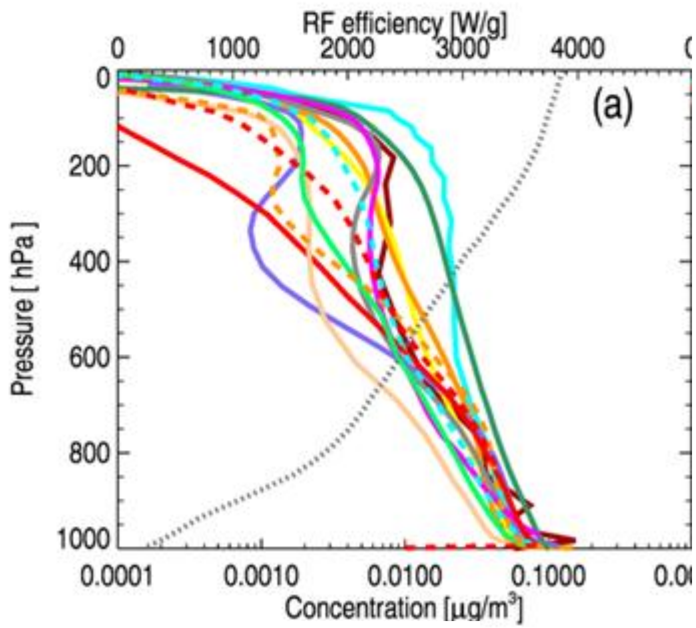
Samset and Myhre (GRL,2011)

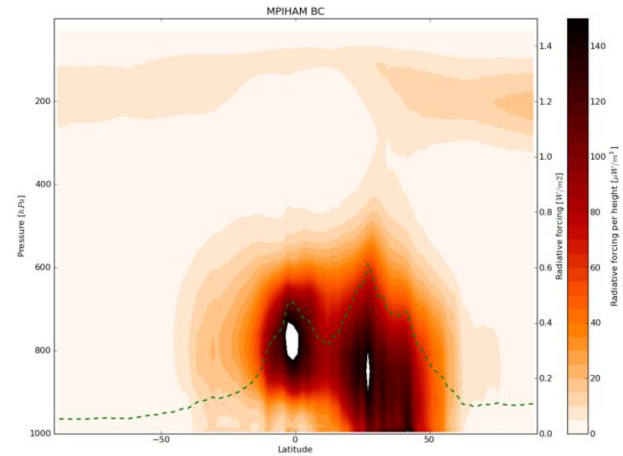


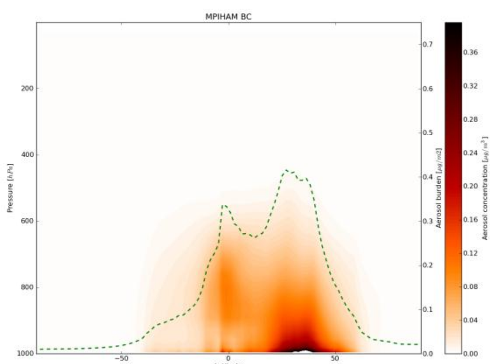
Schwarz et al (GRL,2010)

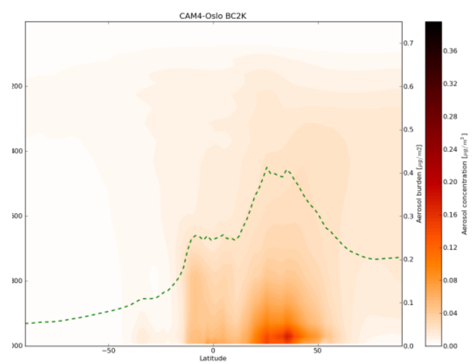
- The above curve – or its full 4D (spatial + temporal) can be combined with modeled concentration profiles to recalculate BC RF
- This removes variability due to cloud fields, optical properties, microphysics, …

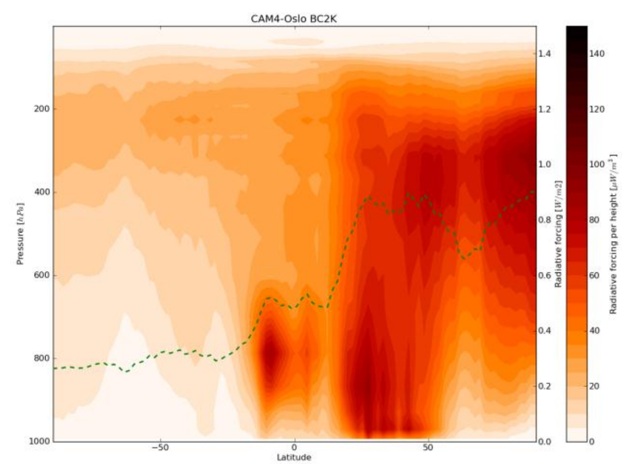
To isolate vertical variability: Concentration profiles of anthropogenic BC from 14 global aerosol models (11 P2 + 3 P1), combined with BC RF efficiency profile, to make 4D BC RF maps



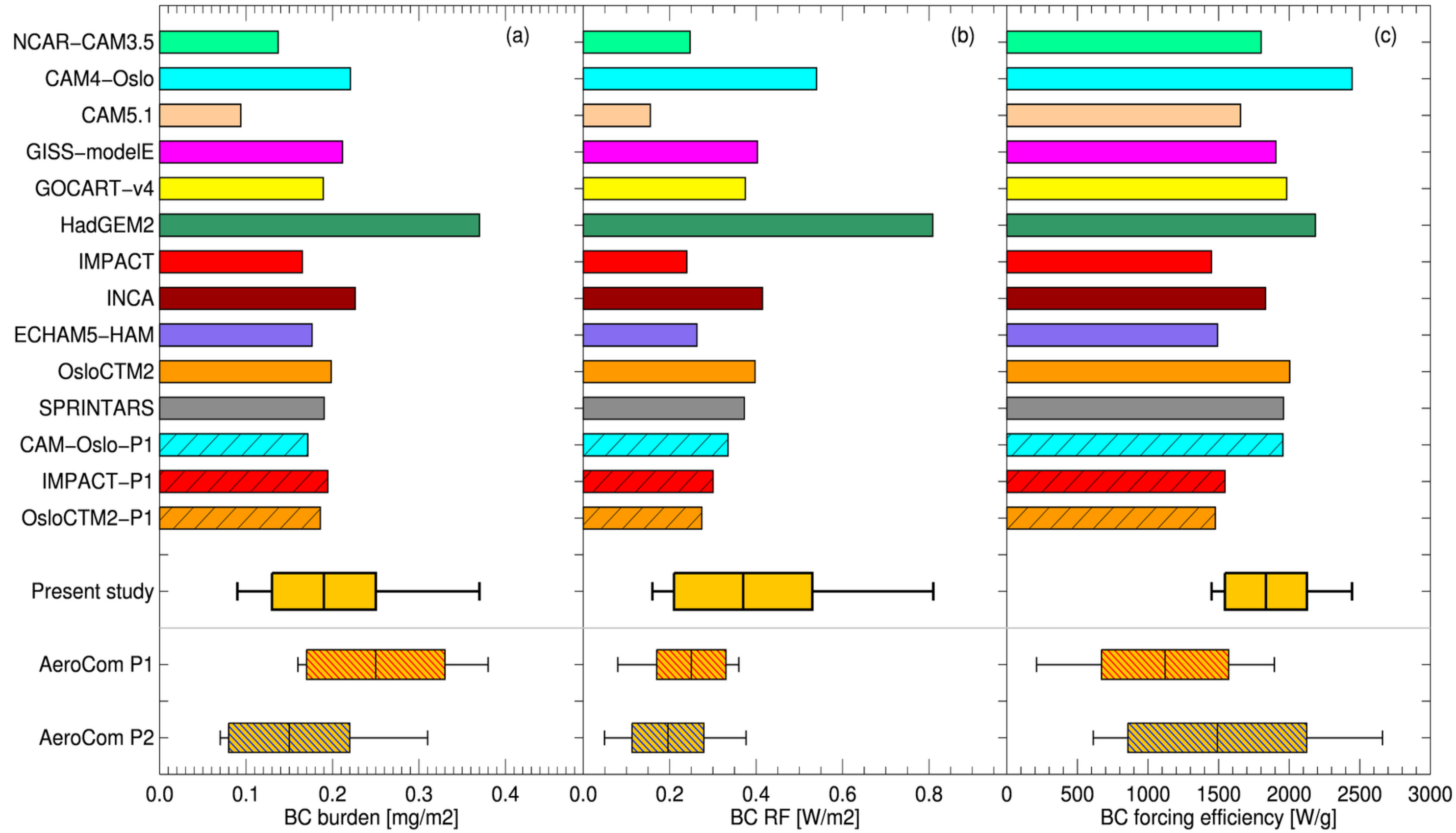






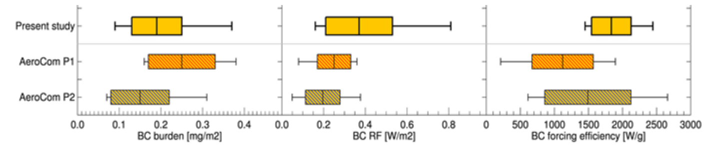


We recalculate BC RF using efficiency profiles, then divide by burden. Differences due to cloud fields, radiative transfer, optical properties are removed. Remaining variability contains information on spatial and temporal diversity.



A range for the vertical sensitivty impact can be estimated from the relative standard deviations and correlations

$RSD_X = \sigma_X / x$ Relative standard deviation



AeroCom P1 and P2: $RSD_{Burden} \approx RSD_{Forcing\ efficiency}$

This study: $RSD_{Recalculated\ forcing\ efficiency} \approx 0.5\ RSD_{Forcing\ efficiency\ in\ P1\ and\ P2}$

$RSD_{Recalculated\ forcing\ efficiency,\ vertical\ only} \approx 0.4\ RSD_{Forcing\ efficiency\ in\ P1\ and\ P2}$

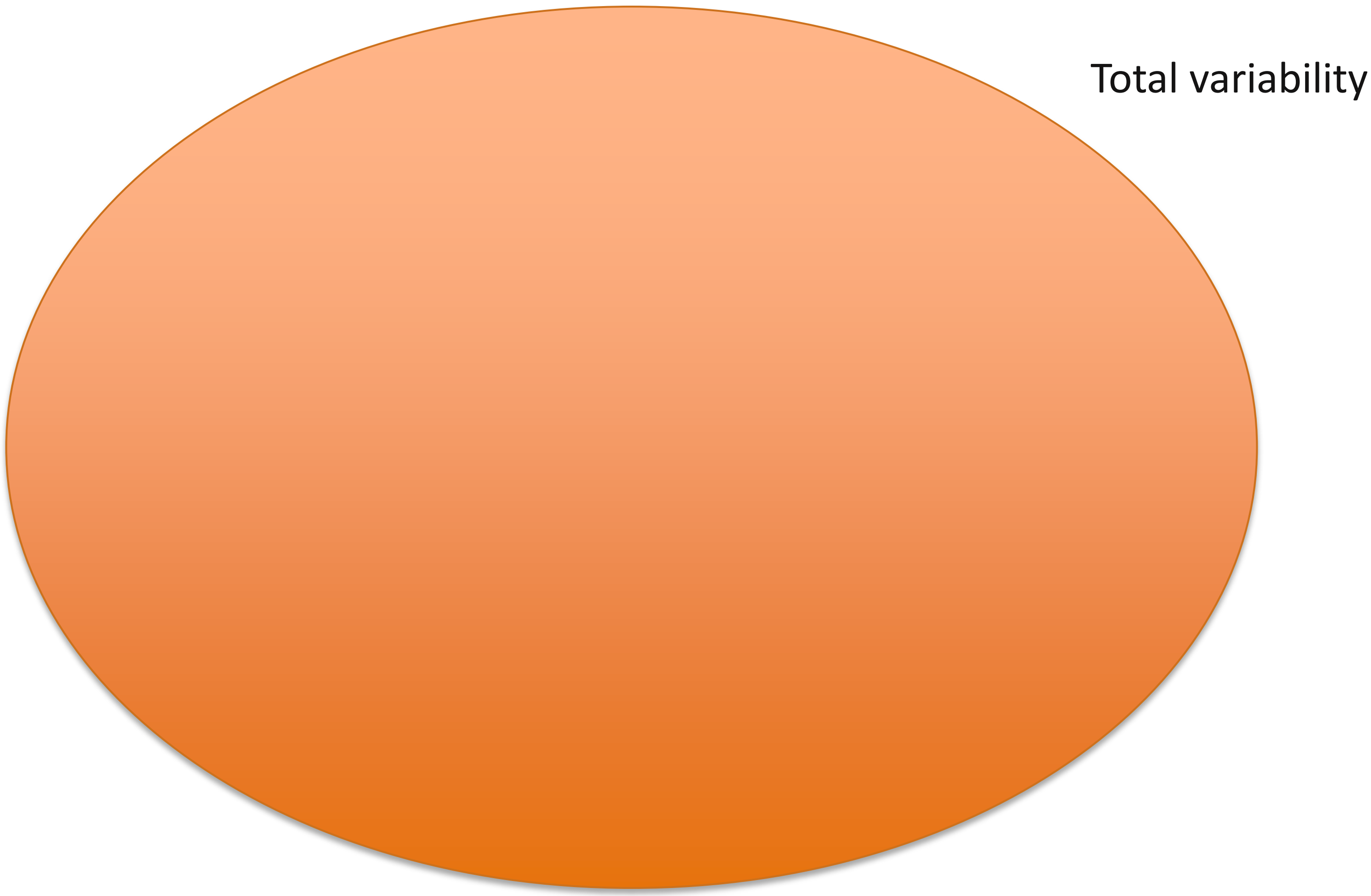
Minimum estimate: <u>Vertical profiles contribute at least 20% of the variability.</u>

However:
In AeroCom P1 and P2, RSD_{Burden} and $RSD_{Forcing\ efficiency}$ are anticorrelated.
I.e. if a model has a high burden, in most cases it compensates by a low efficiency.

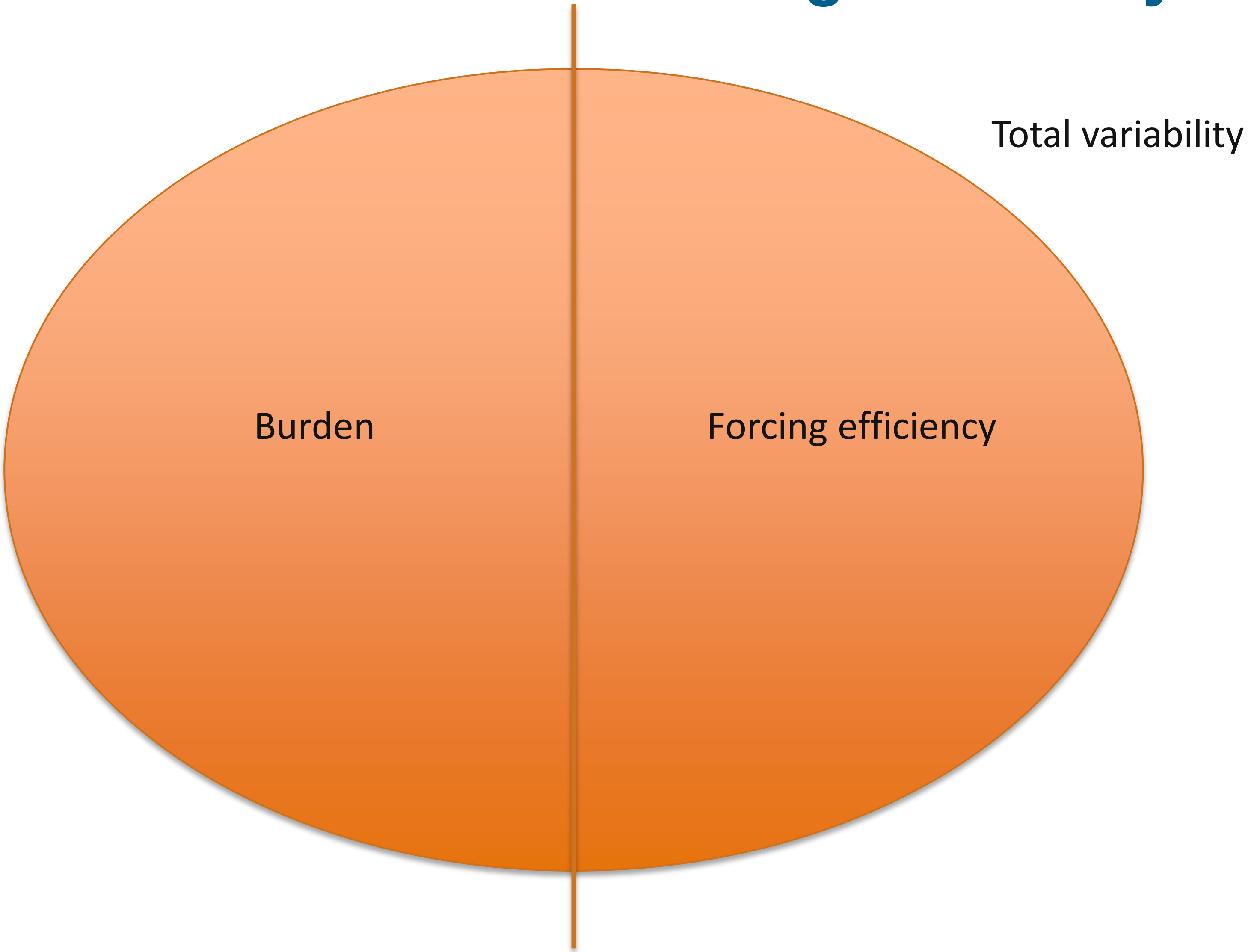
In the present study, we find a posive correlation between the mass simulated above 5km and both modeled burden and forcing efficiency. The vertical variability therefore does not contribute to the observed anticorrelation – rather the opposite.

Maximum estimate: <u>Vertical profiles can contribute up to 50% of the variability.</u>

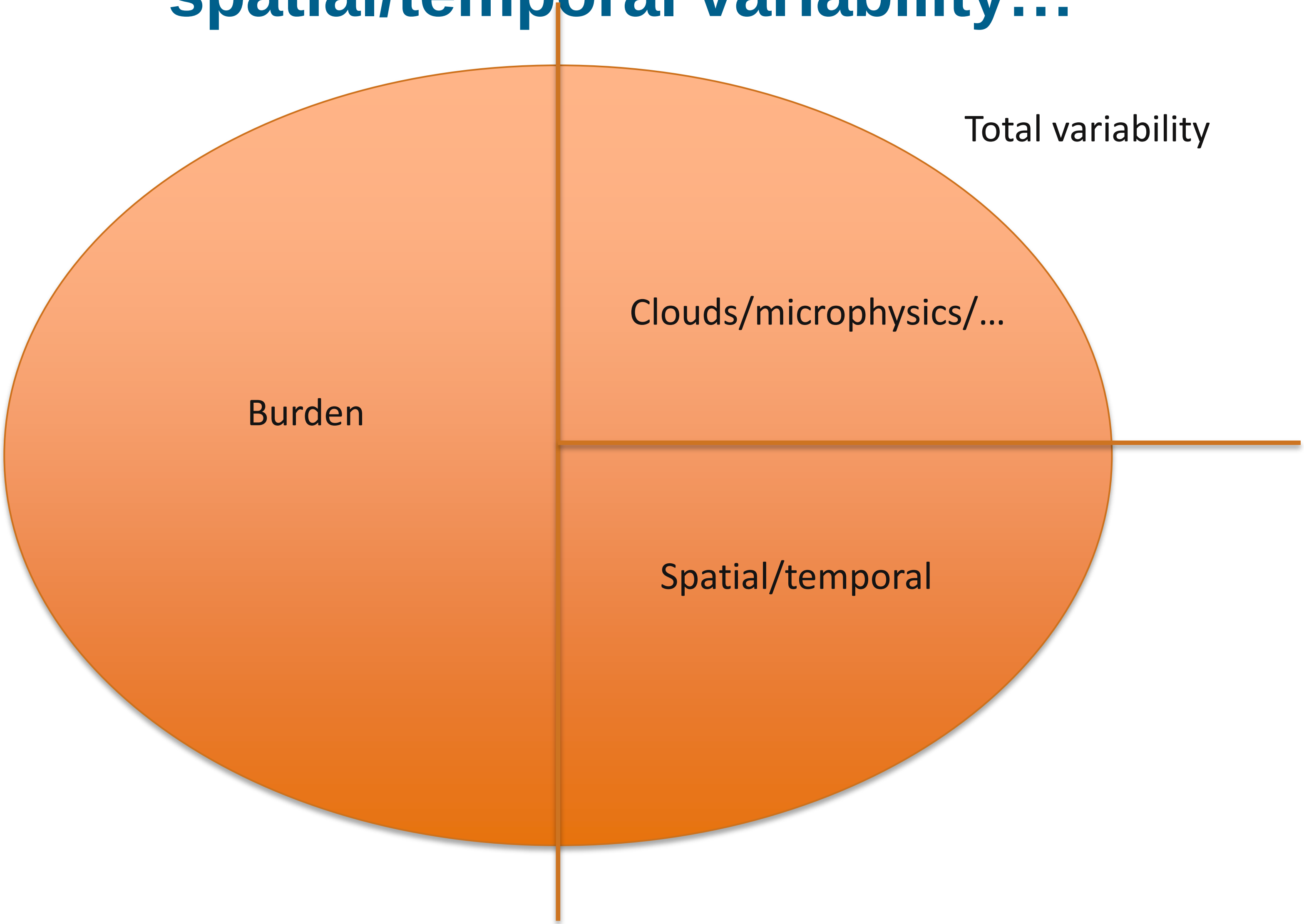
The total variability on modeled BC forcing…



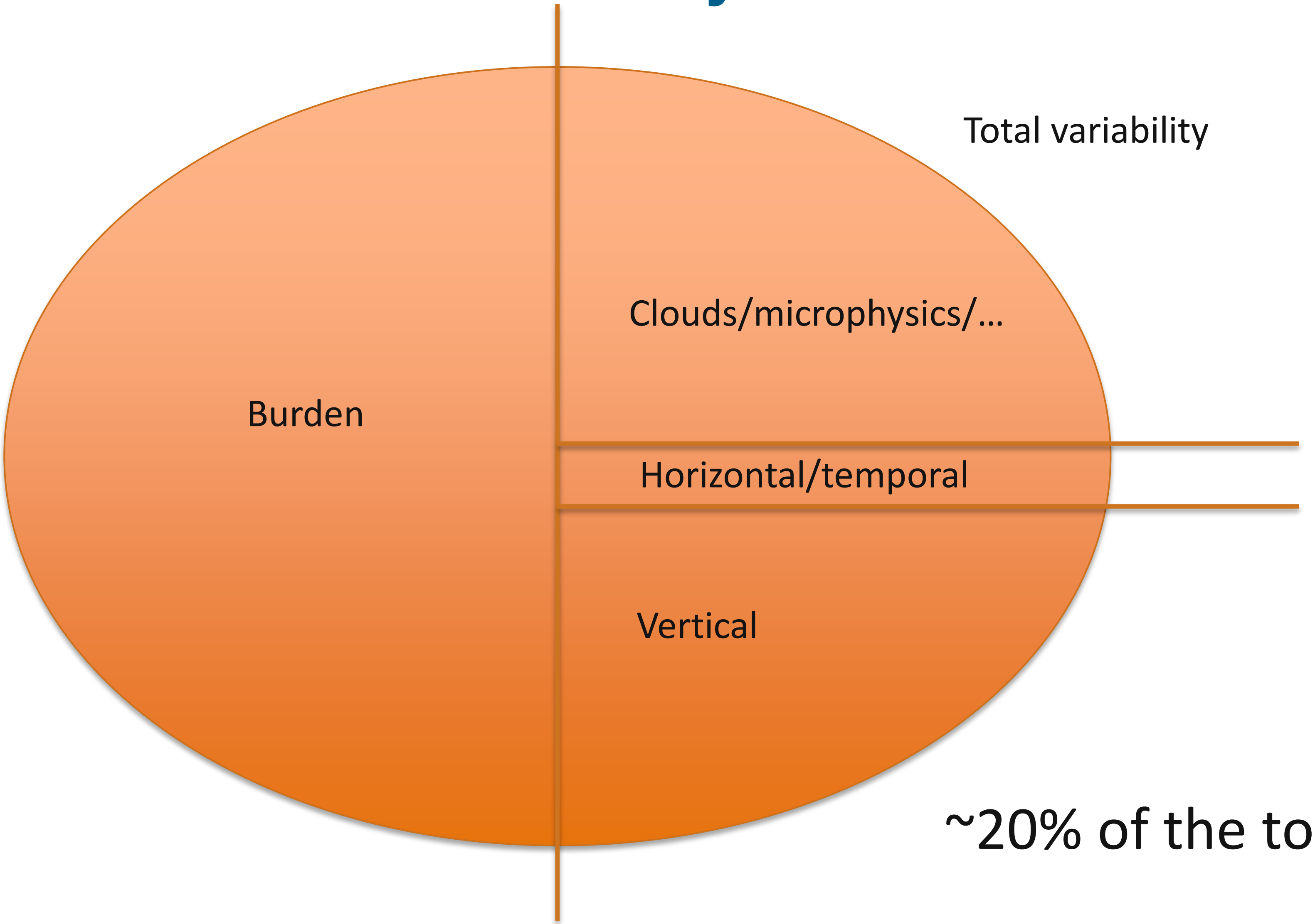
…is, in AeroCom P1 and P2, equally divided between burden and forcing efficiency…



…of the latter, 50% can be explained by spatial/temporal variability…

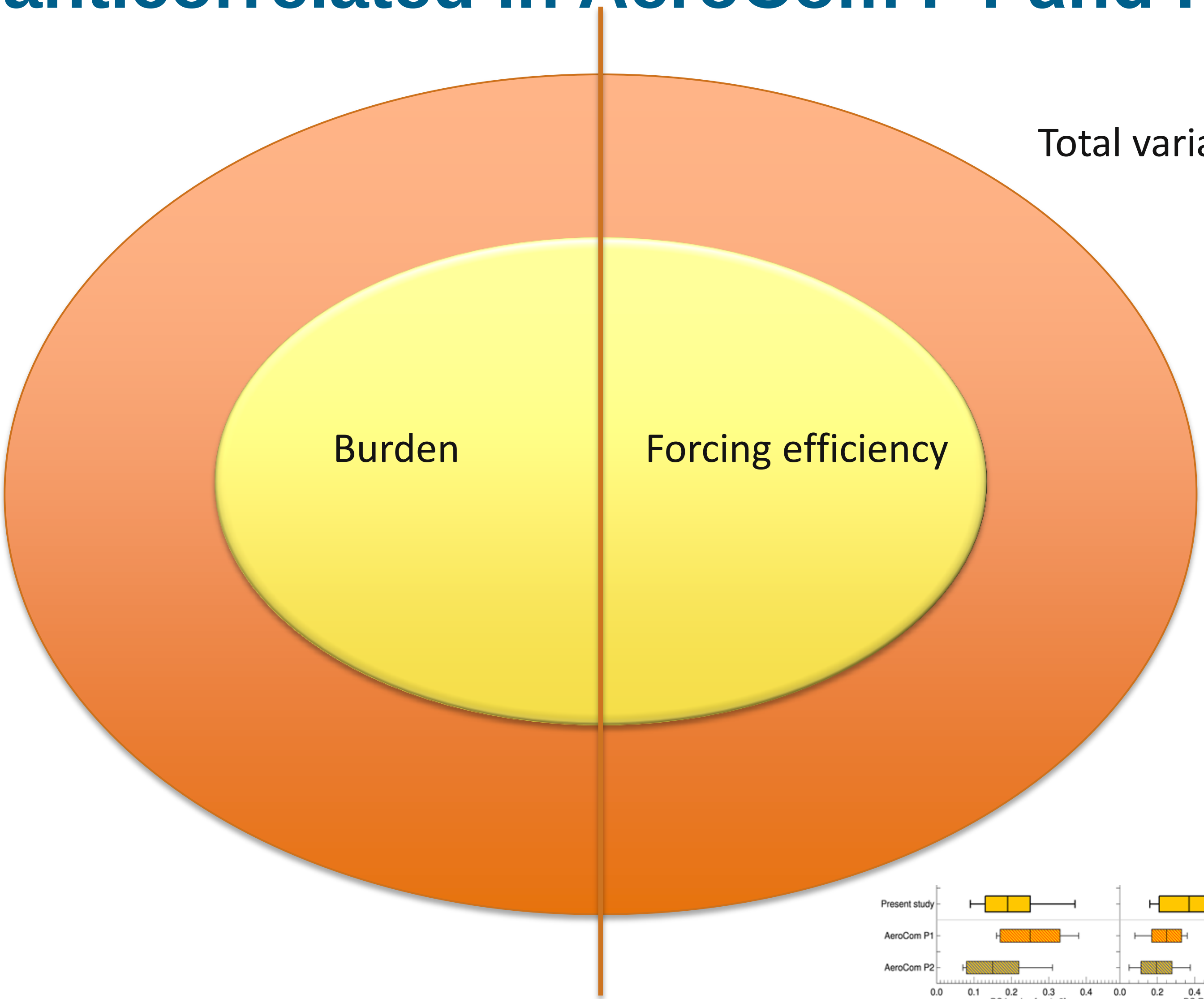


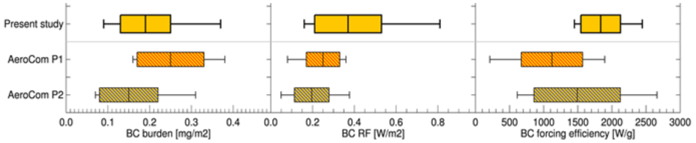
…of which the majority is due to the vertical variability…



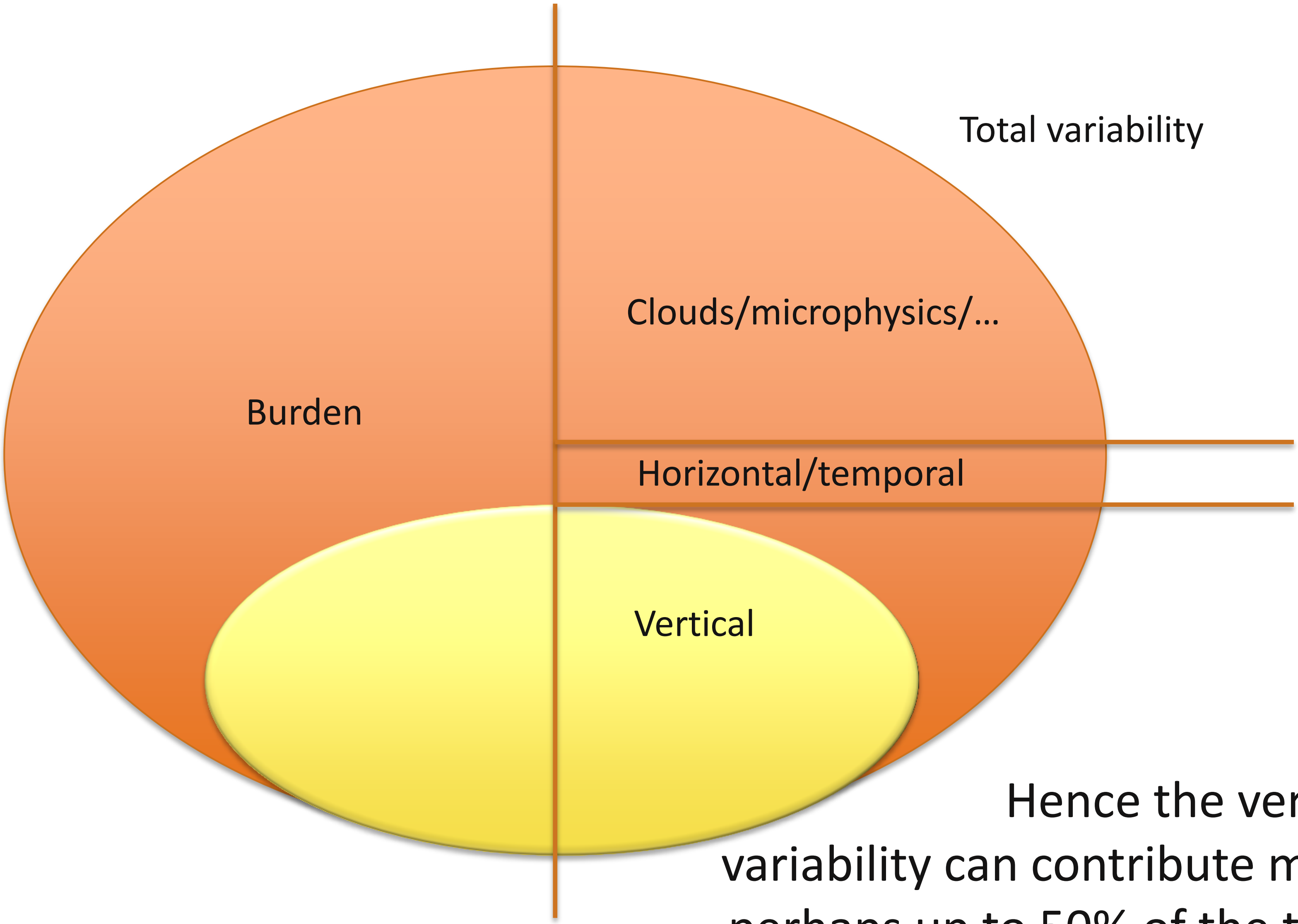
~20% of the total

But: the burden and forcing efficency are anticorrelated in AeroCom P1 and P2…



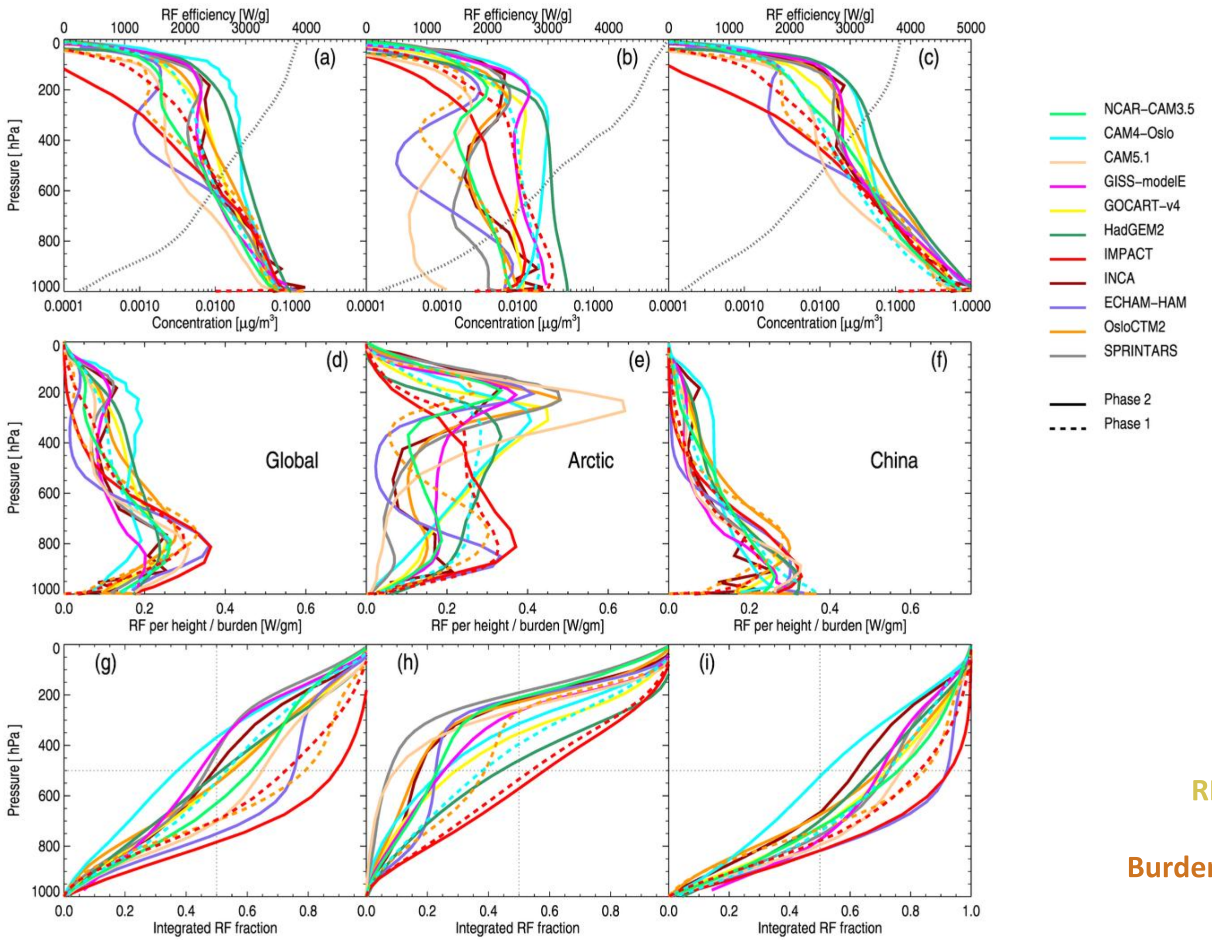


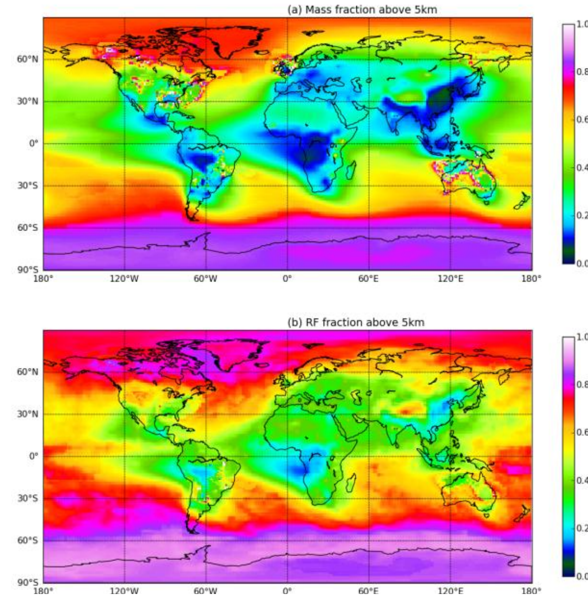
…while the vertical variability is positively correlated with the burden.

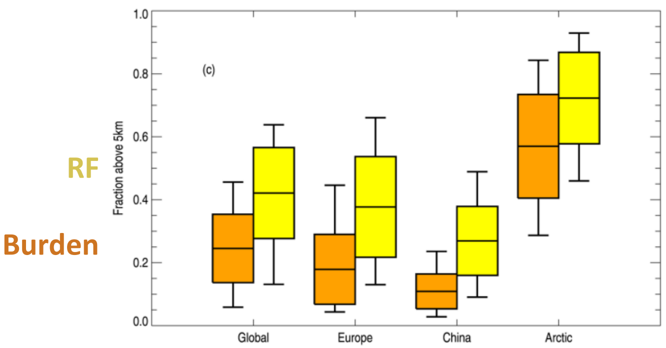


Hence the vertical variability can contribute more, perhaps up to 50% of the total.

Regional features of vertical variability

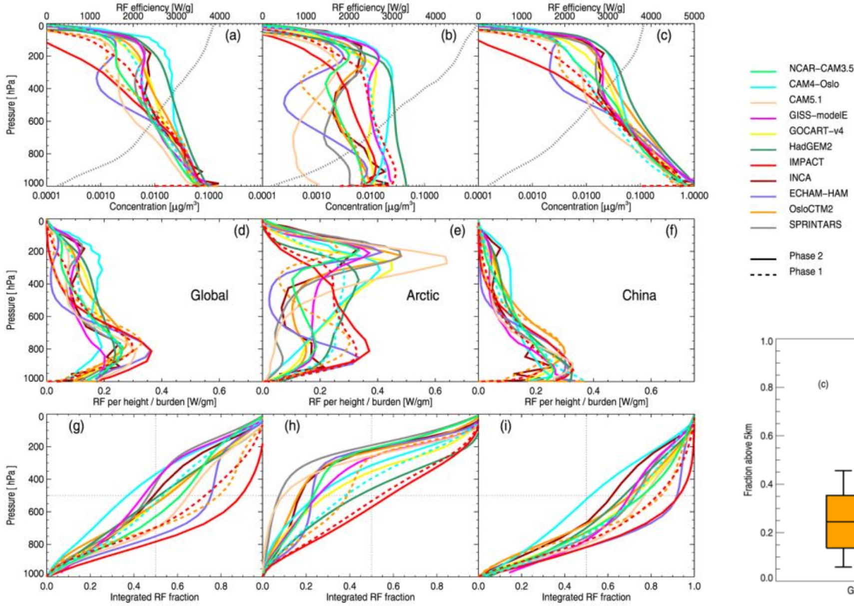




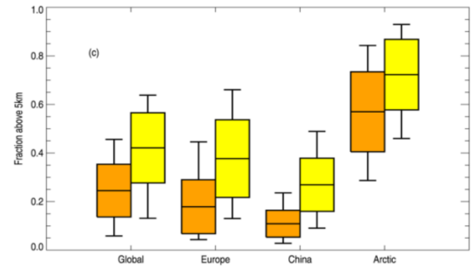


We note a distinction between primary emission regions (e.g. China) and transport regions (e.g. the Arctic). Fraction of RF exerted above 5km can be as high as 75%.

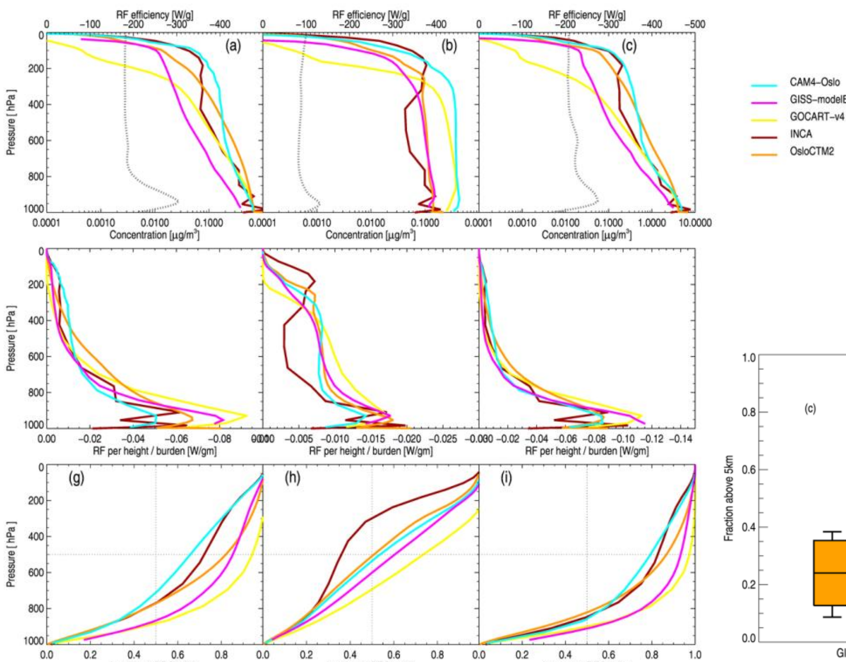
Comparison of black carbon with sulphate



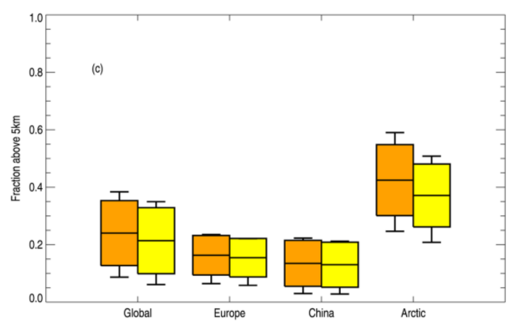
BC



- BC diversity driven by differences in burden and vertical sensitivity
- SO4 likely more sensitive to model differences in relative humidity (under investigation)



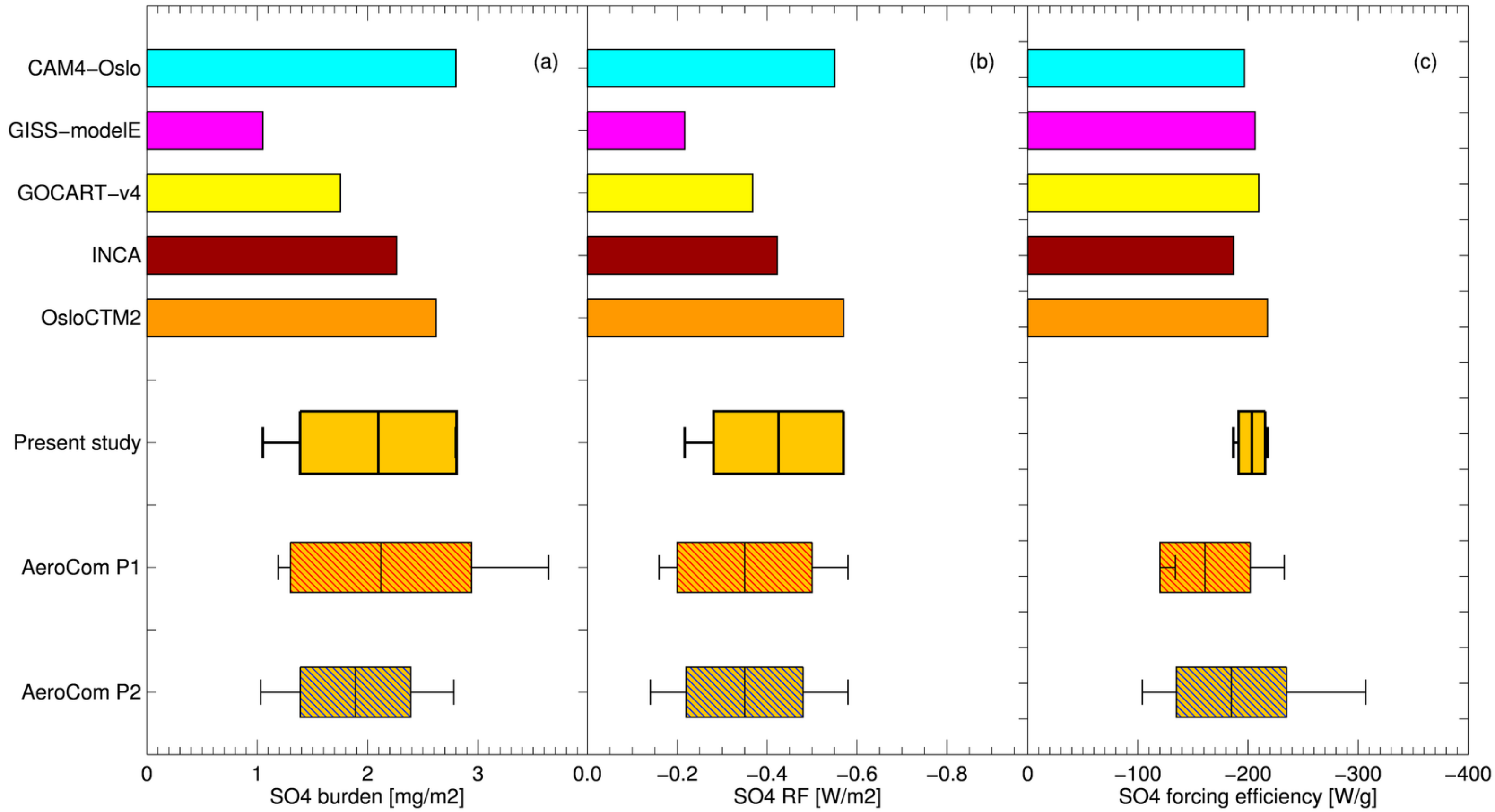
SO4



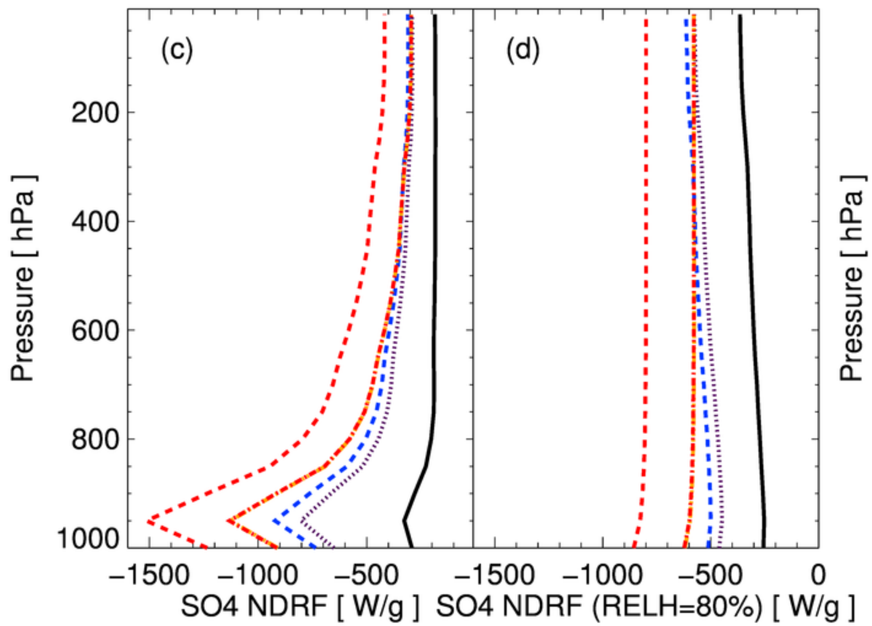
RF

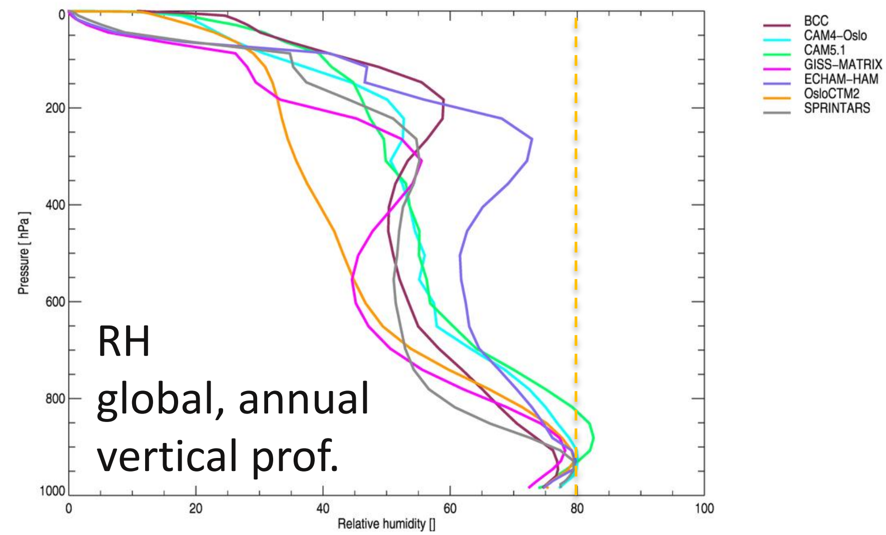
Burden

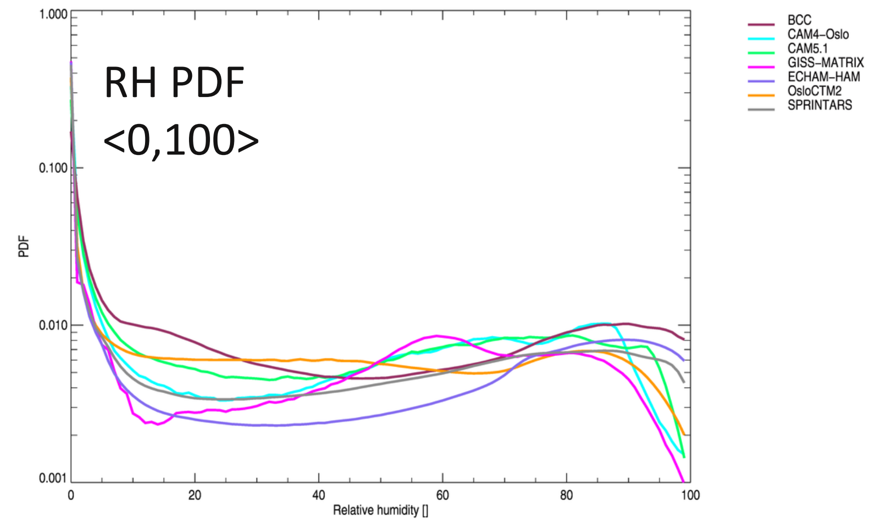
Using the OsloCTM2 forcing efficiency reduces the SO4 NRF variability to essentially 0, i.e. main variability is due to burden changes. BUT…



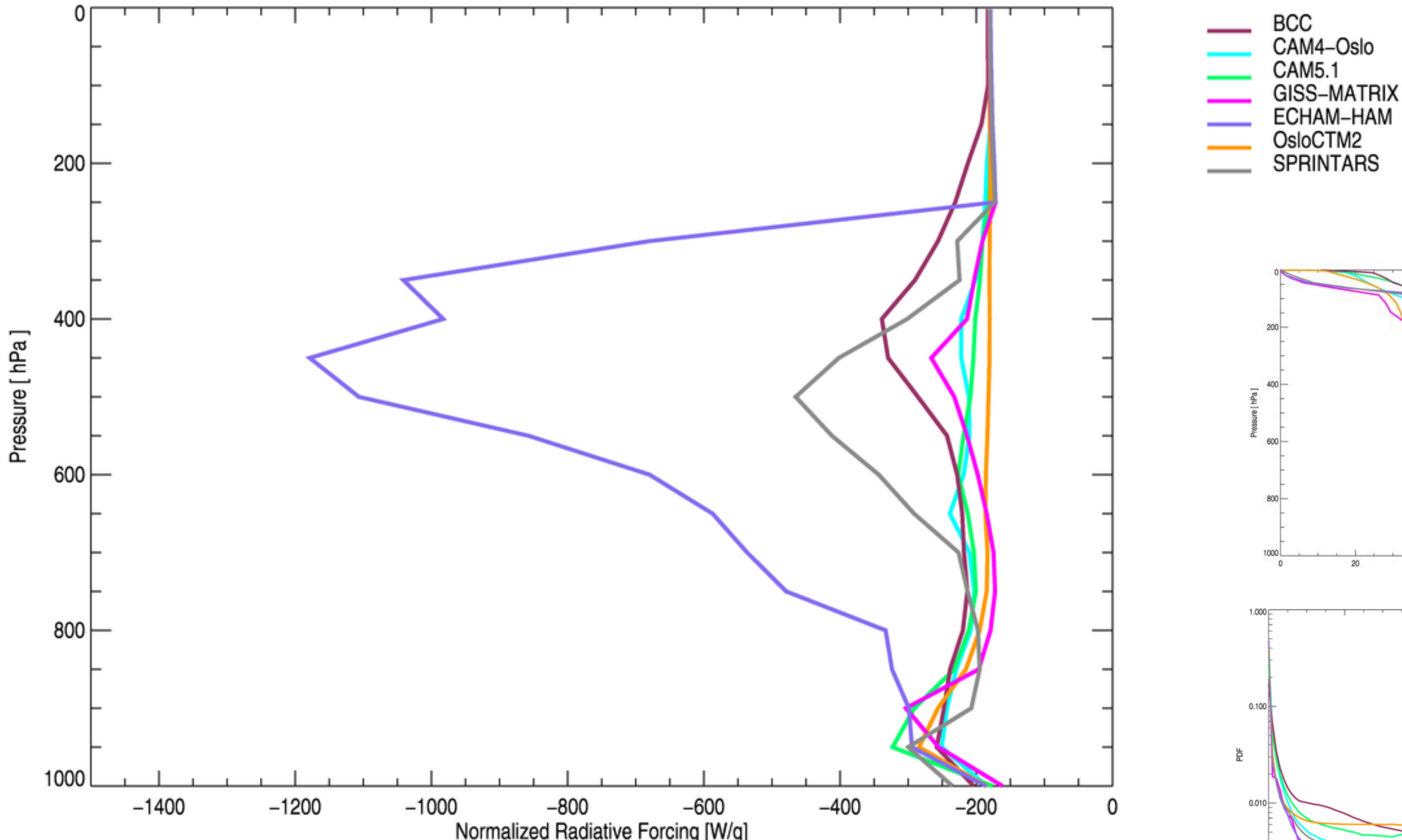
Sulphate relative humidity vertical profiles and PDFs

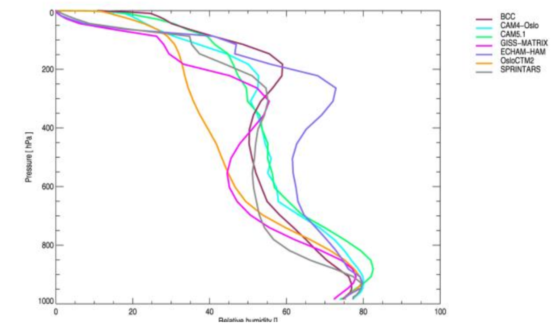


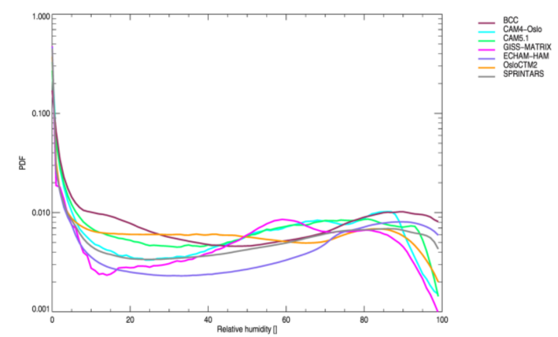




Sulphate efficiency profiles with individual model HUM and TEMP fields run through our radiation code







We propose to further develop this analysis, and will contact the modeling groups for further info and collaboration.

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Conclusions

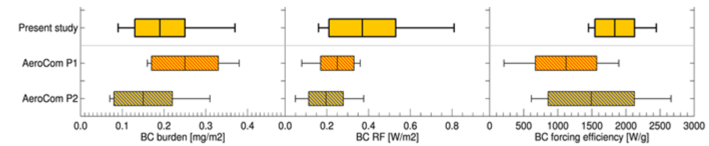
BC:

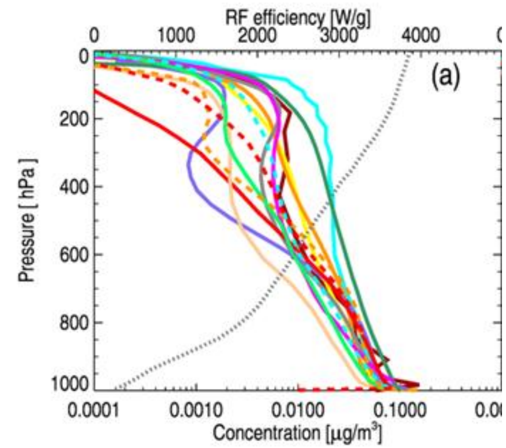
- There is still significant variabilty between model estimates of the anthropogenic radiative forcing of the direct aerosol effect of black carbon
- This vertical variability causes between 20% and 50% of the RF variability
- We see significant differences between emission regions and transport regions

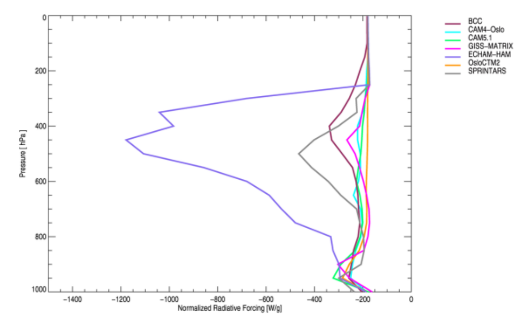
SO4:

- Using single efficiency profile yields no significant variability between models
- Using RH from individual models to calculate efficiency profiles allows us to combine efficiency from one model with concentrations from another
- We aim to pursue this further and will ask for input and collaboration

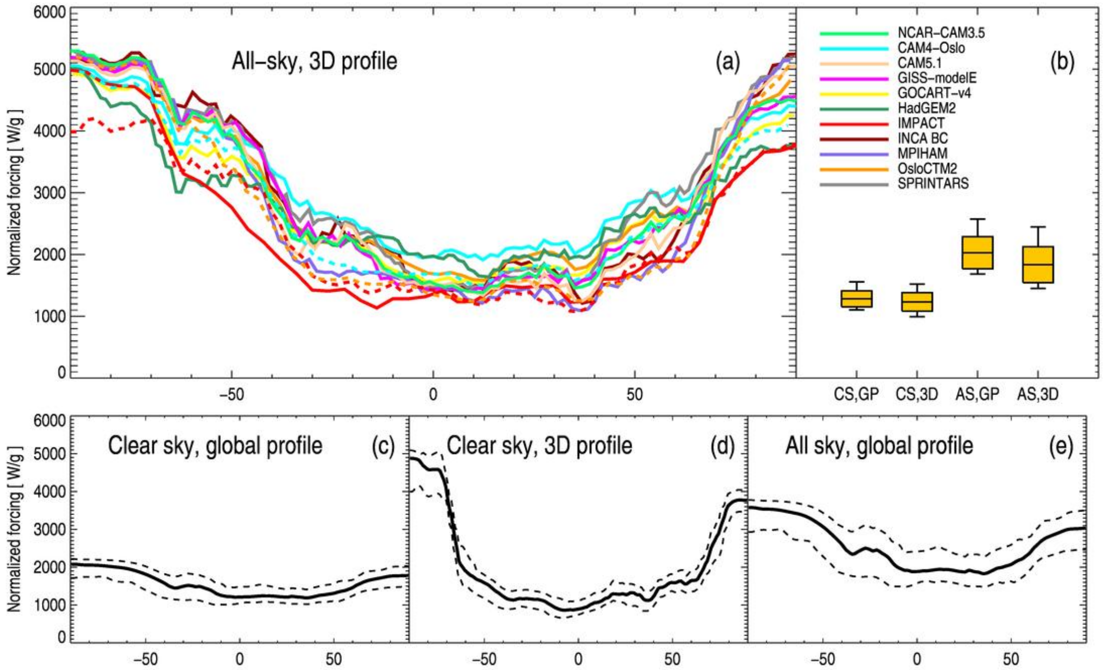
Thanks for listening.







What drives the remaining spatial/temporal variability?



Run the analysis using four efficiency profiles:

- Clear-sky, global mean
- Clear-sky, 4D
- All-sky, global mean
- All-sky, 4D

Model variability in forcing efficiency due to vertical profile differences due to:

- Equal and significant contributions from the cloud field and from regional differences
- A major contribution from the underlying sensitivity of BC forcing to altitude even in the absence of clouds and albedo differences.

Harmonizing model treatment of clouds and albedo is therefore not sufficient to remove uncertainties in BC forcing due to vertical profiles.