CSU
Global modeling and climate effects

Jack Kodros, Jeff Pierce, and the CSU team

Goal

While the data suggest that improving biofuel combustion devices will benefit health, what is the effect on climate?

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e.g. where do we need help?!

Biofuel vs. cookstoves

- We focus here on biofuel (mostly) due to current emissions inventories
- Biofuel for as other energy sources (e.g. heating/lighting) is included here
- Coal as cookstove fuel is not included as biofuel
  - We perform one sensitivity simulation to test this over Asia

Biofuel Climate Effects

- GHGs: CO_2, CH_4, VOCs
- Aerosol direct effect (scatter/absorb sunlight) (?)
- Aerosol indirect and semi-direct effect (affect cloud albedo/lifetime/amount) (??)
- Black carbon on snow (?)
- Aerosol driven circulation changes (???)

??? - level of uncertainty in magnitude

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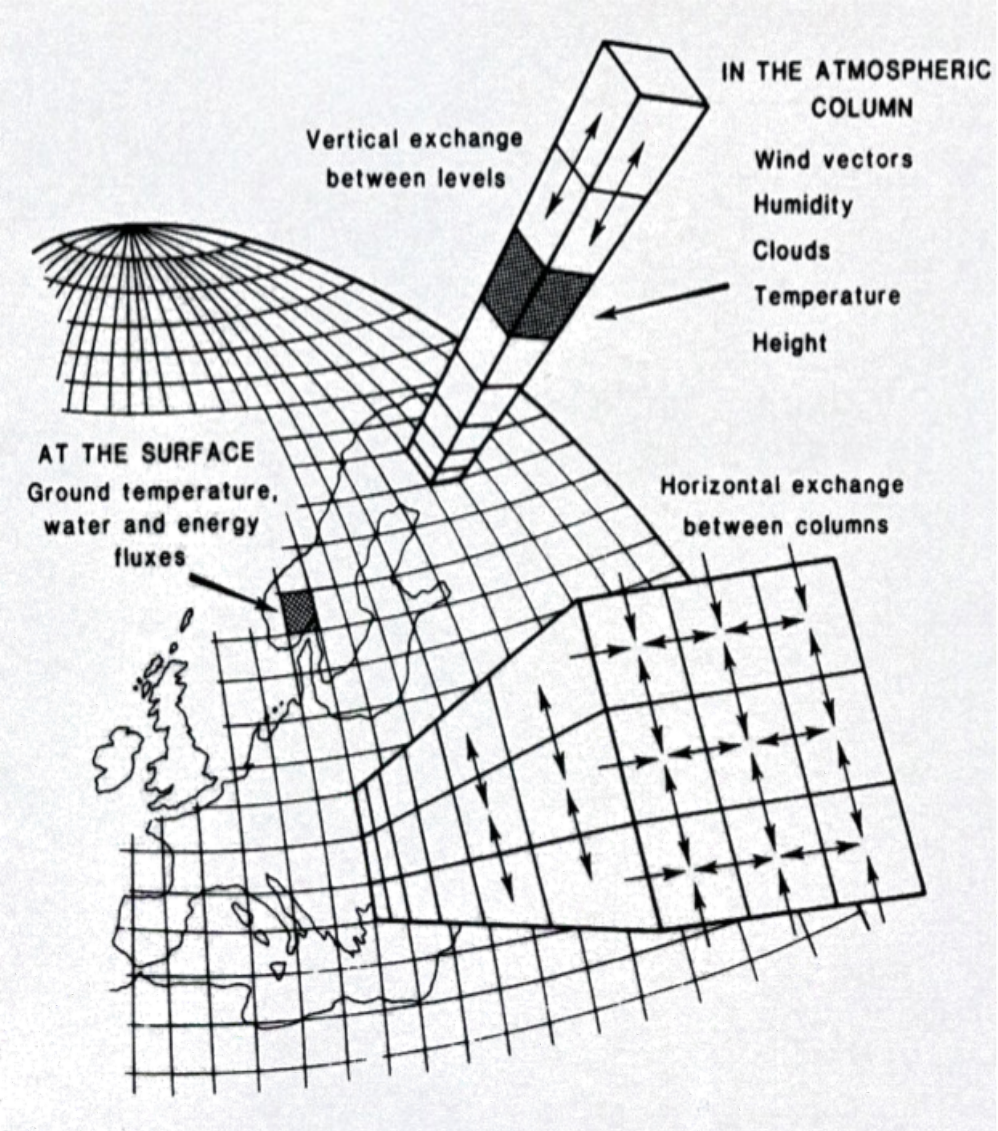
GEOS-Chem-TOMAS



- GEOS-Chem version 9.02
  - 4 x 5° horizontal resolution
  - 47 vertical layers
  - GEOS-5 met fields
- TOMAS
  - Aerosol microphysics
  - 15 size sections: 3nm – 10 μm
  - Species: sulfate, sea-salt, OA, BC, dust

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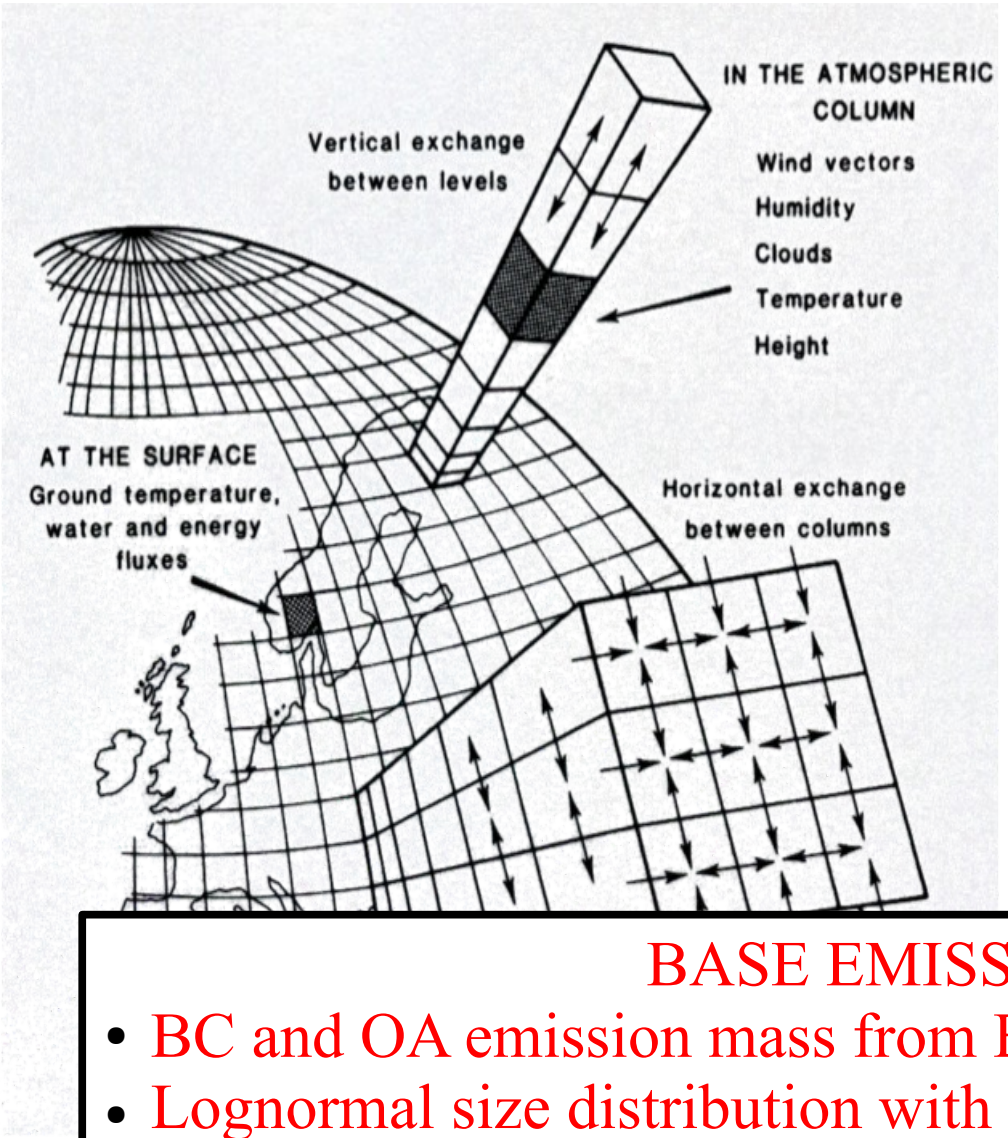

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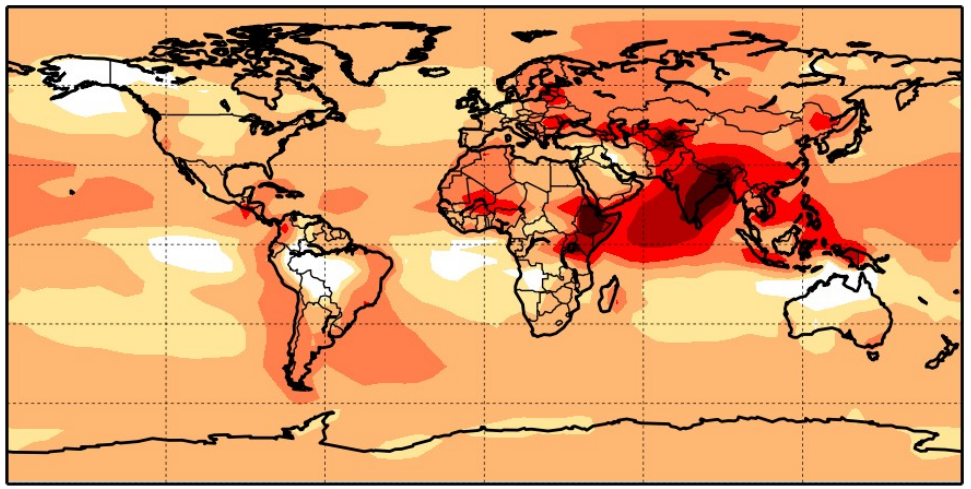
BASE EMISSIONS DETAILS

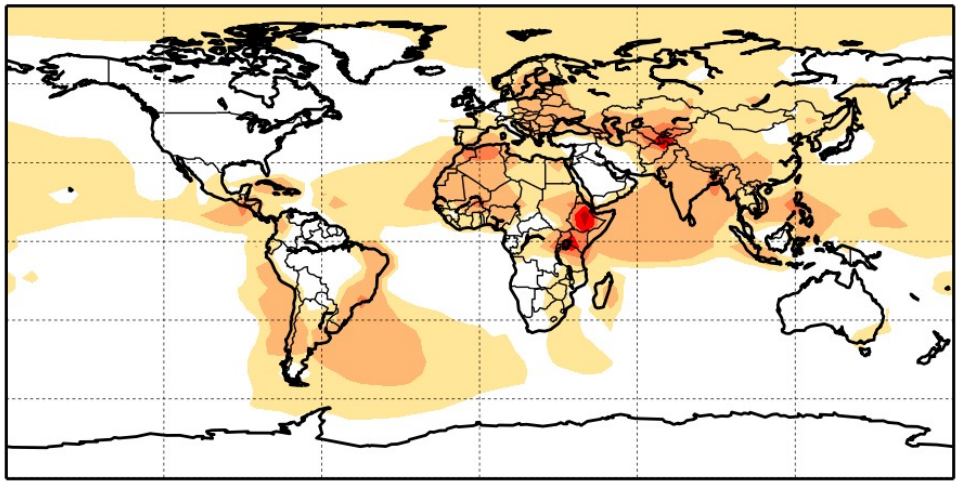
- BC and OA emission mass from Bond et al. (2007) (biofuel only)
- Lognormal size distribution with median D_p=100 nm and σ=2.0

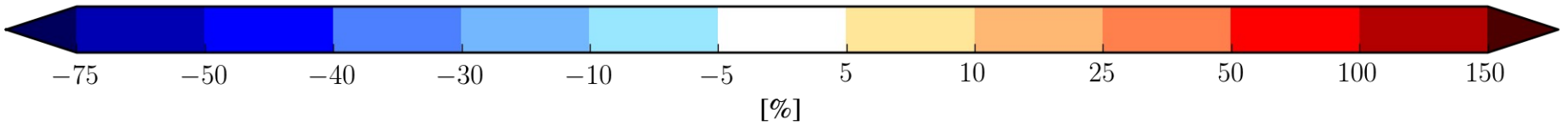
BC and OA Mass increases due to biofuel

BC Boundary Layer % Change
Global Mean: 30%



OA Boundary Layer % Change
Global Mean: 8%





Key uncertainties to test

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- Hygroscopicity

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Chemical properties

- Emissions median diameter
- Emissions modal width

"Aged" particle size

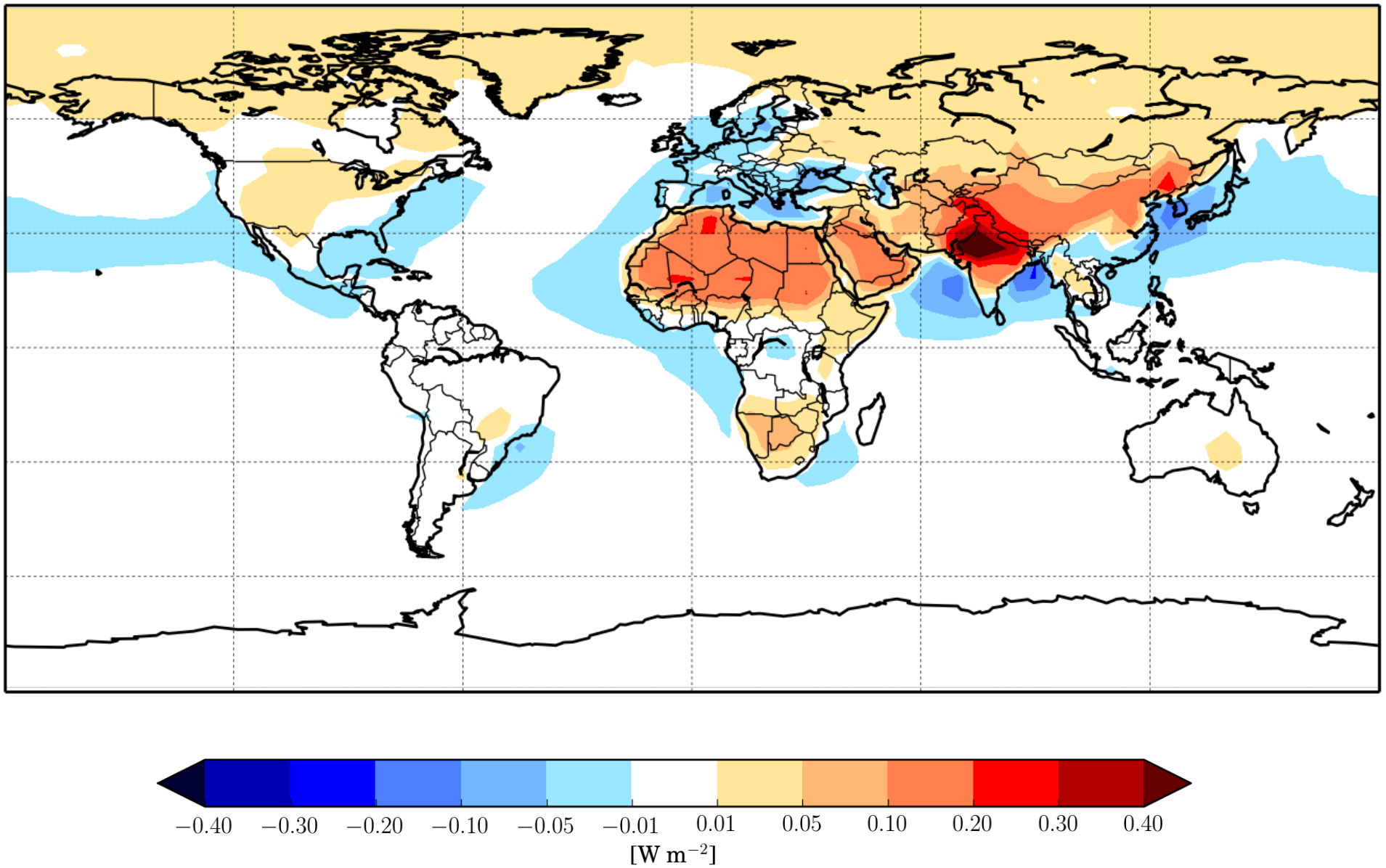
- Optics
- Residential coal (not included in base inventory)
- Background SOA
- Nucleation

Non-biofuel model parameters

Direct Radiative Effect
Uncertainties due to optics only

DRE – Core-Shell

Global Mean: +0.007 W m^{-2}



Assumptions for optics calculations

Internal

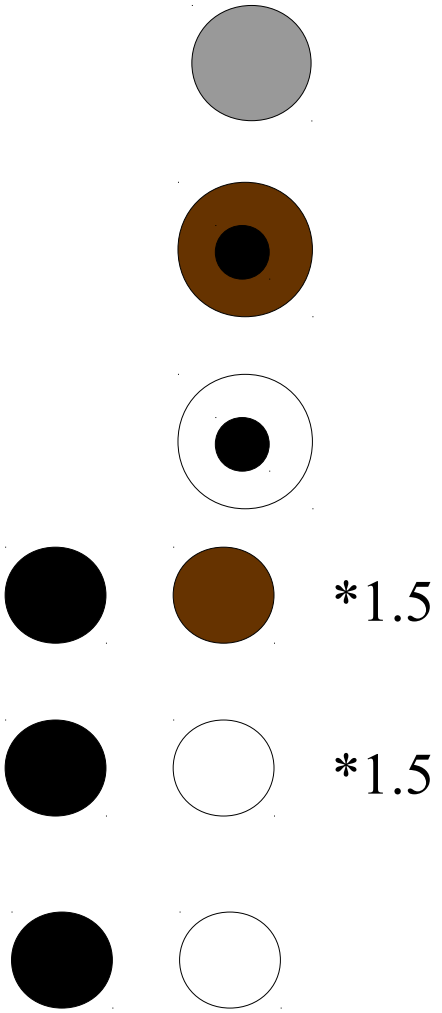
Core-Shell (absorptive OA)

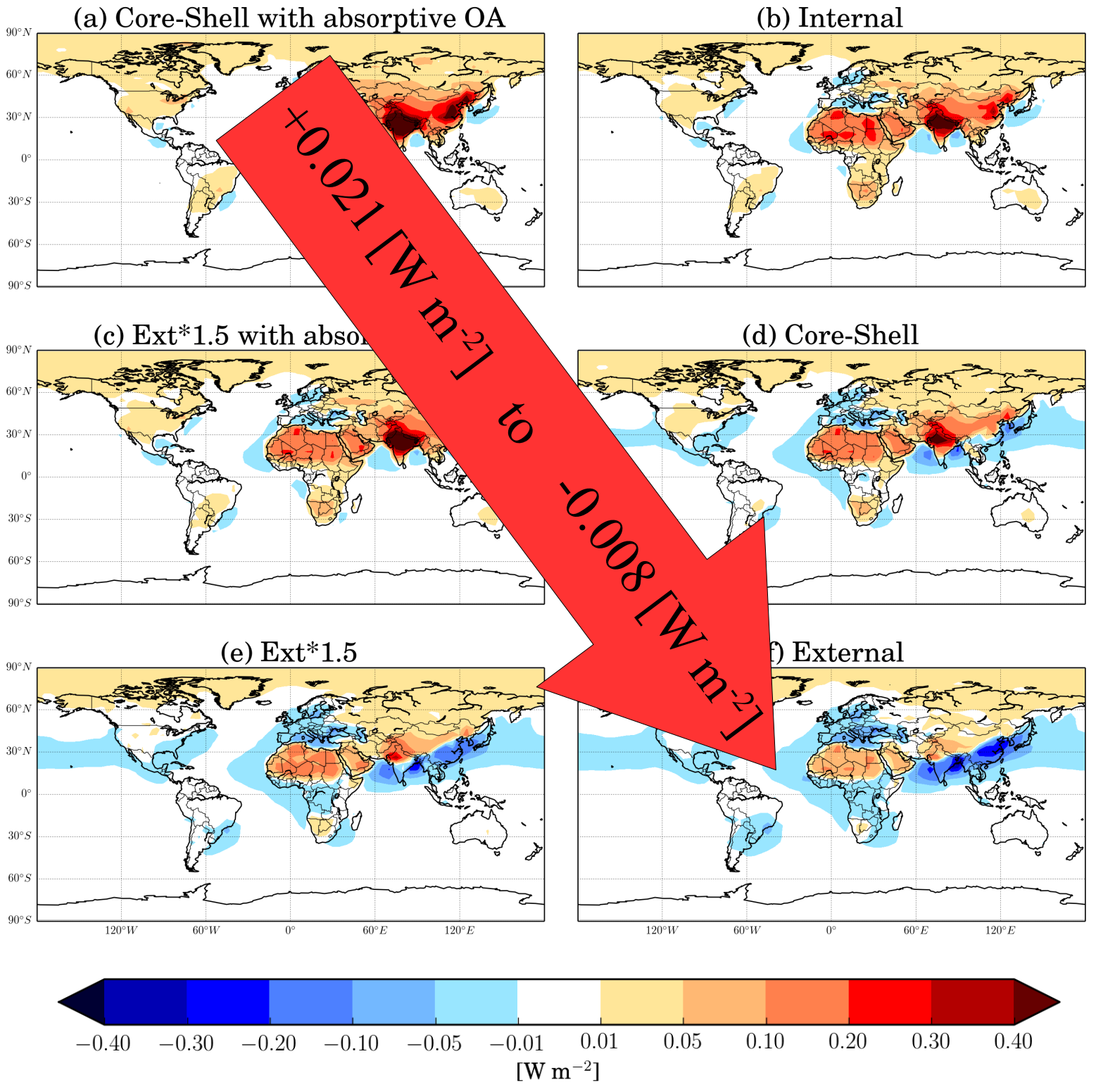
Core-Shell

Ext*1.5 (absorptive OA)

Ext*1.5

External




(a) Core-Shell with absorptive OA
(b) Internal
(c) Ext*1.5 with abso
(d) Core-Shell
(e) Ext*1.5
f) External
+0.021 [W m-2] to -0.008 [W m-2]
90°N
60°N
30°N
0°
30°S
60°S
90°S
120°W
60°W
0°
60°E
120°E
−0.40 −0.30 −0.20 −0.10 −0.05 −0.01 0.01 0.05 0.10 0.20 0.30 0.40
[W m−2]

Cloud Albedo Indirect Effect

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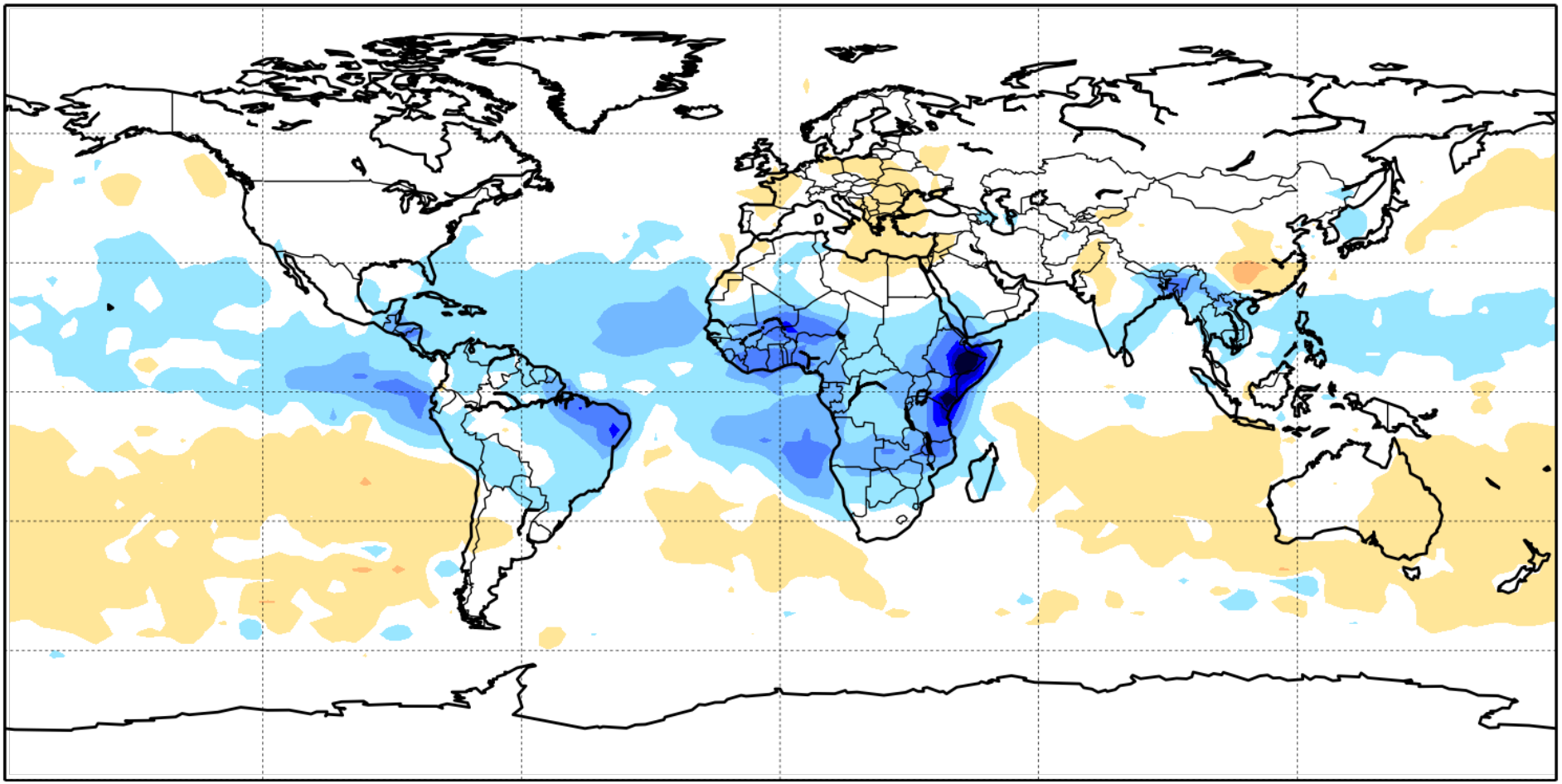
Global Mean: -0.006 W m^{-2}



Cloud Albedo Indirect Effect

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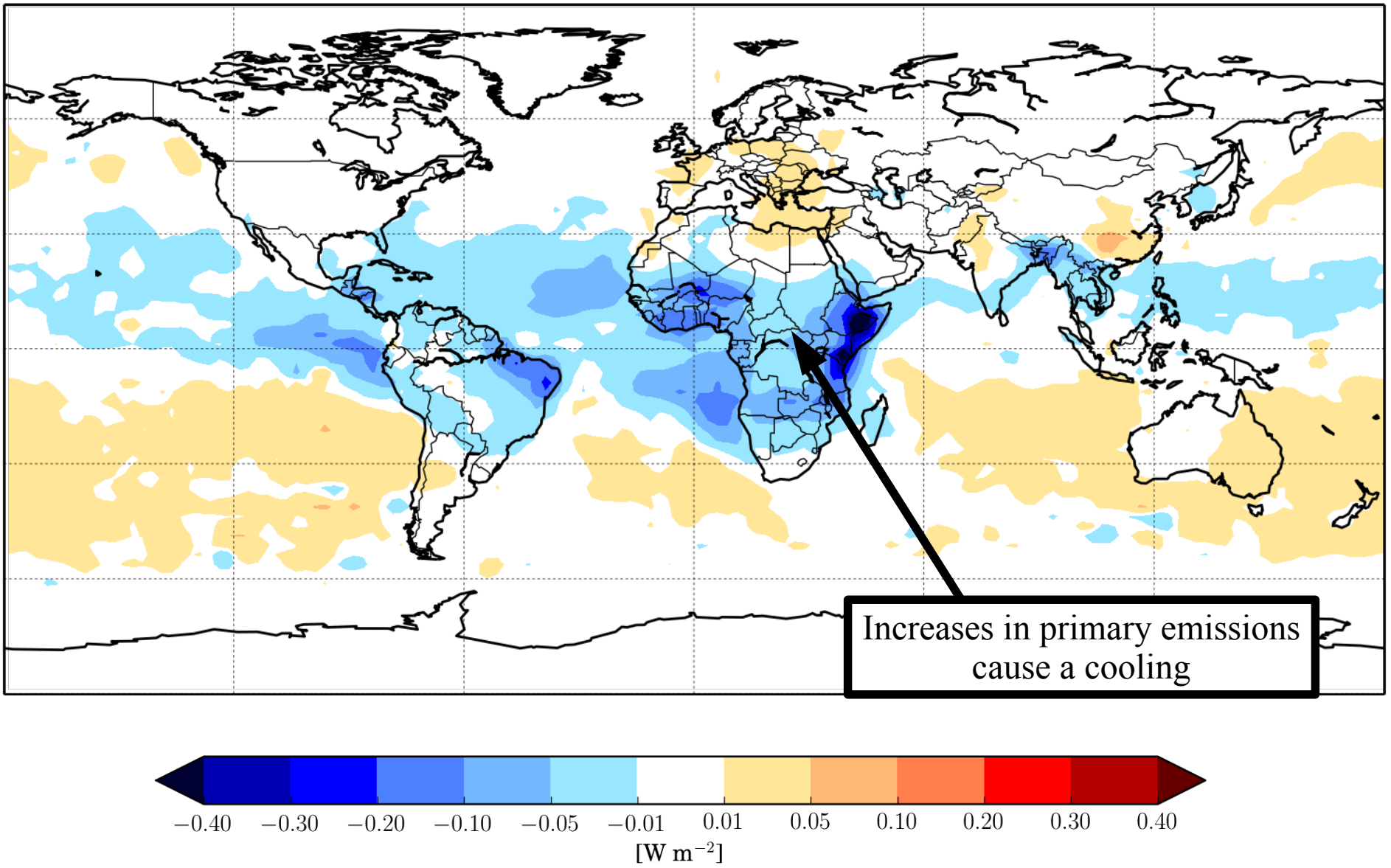

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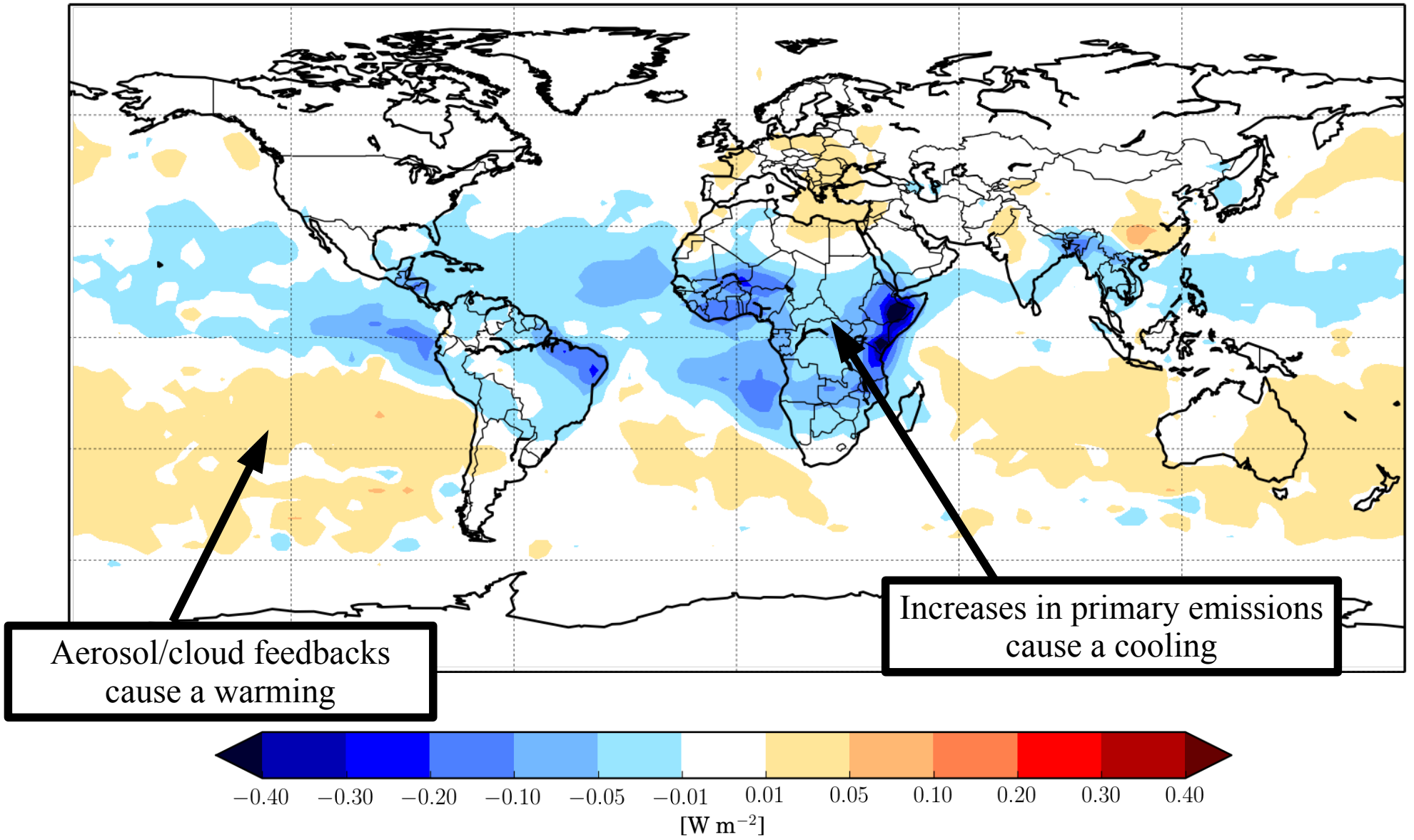

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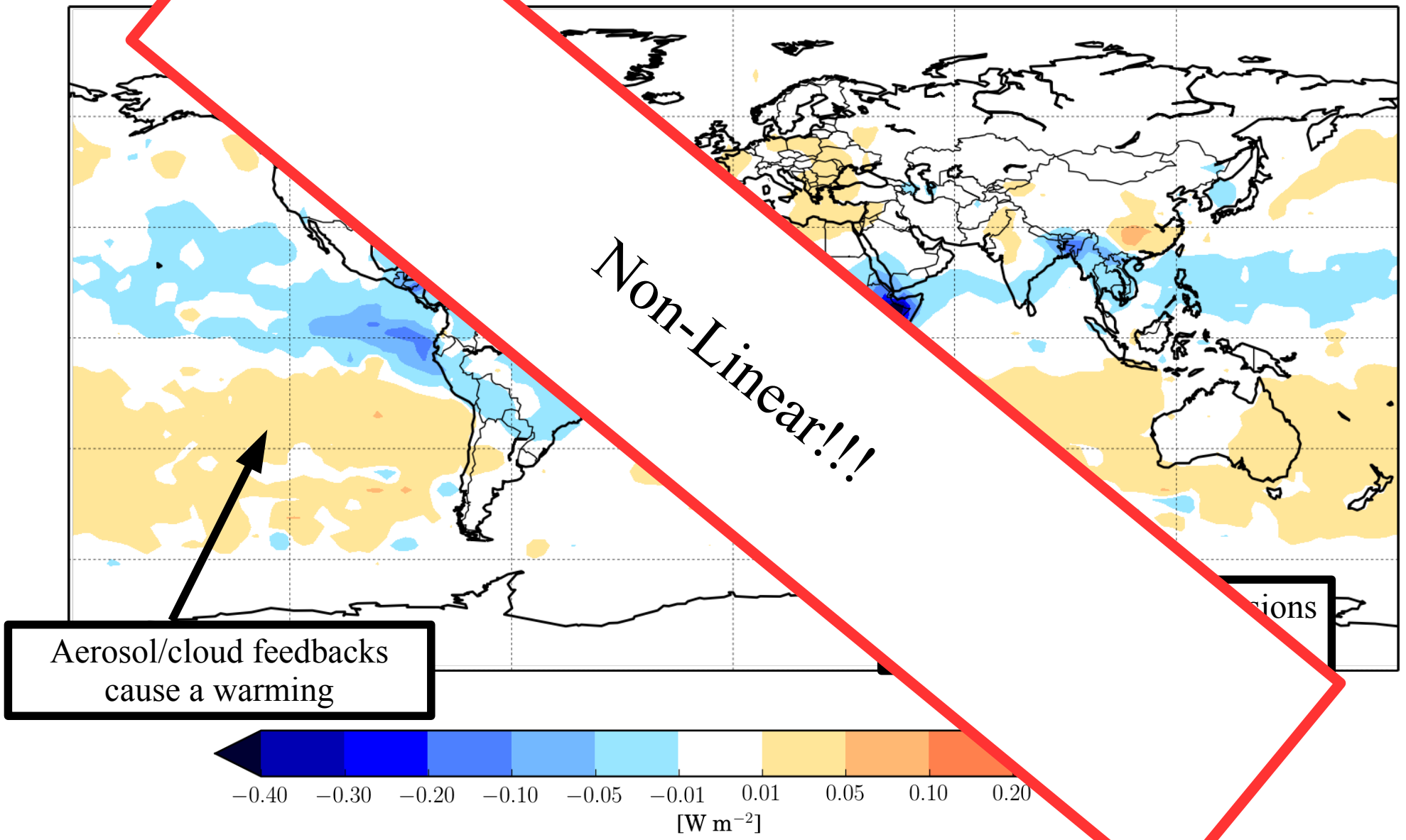
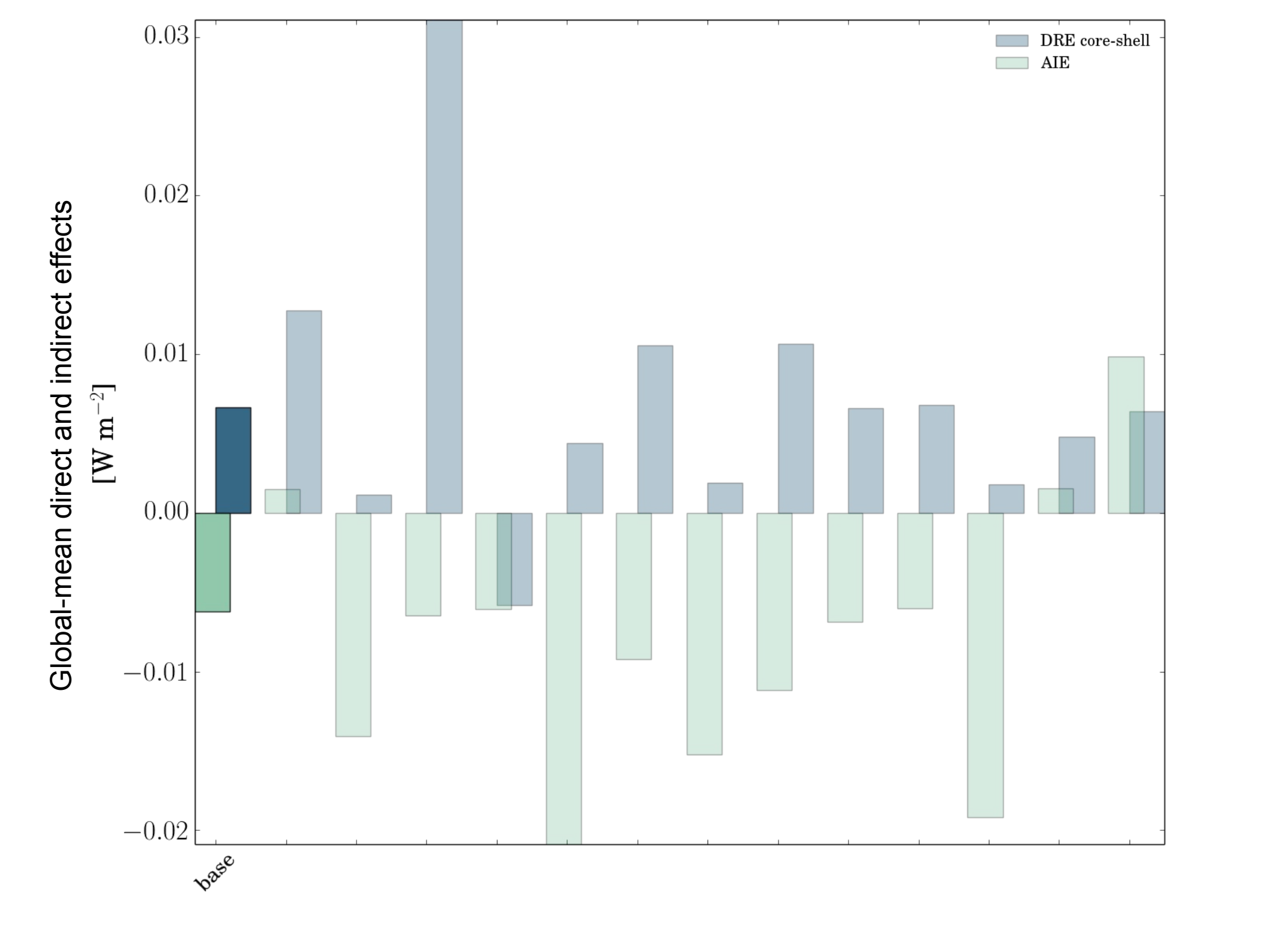
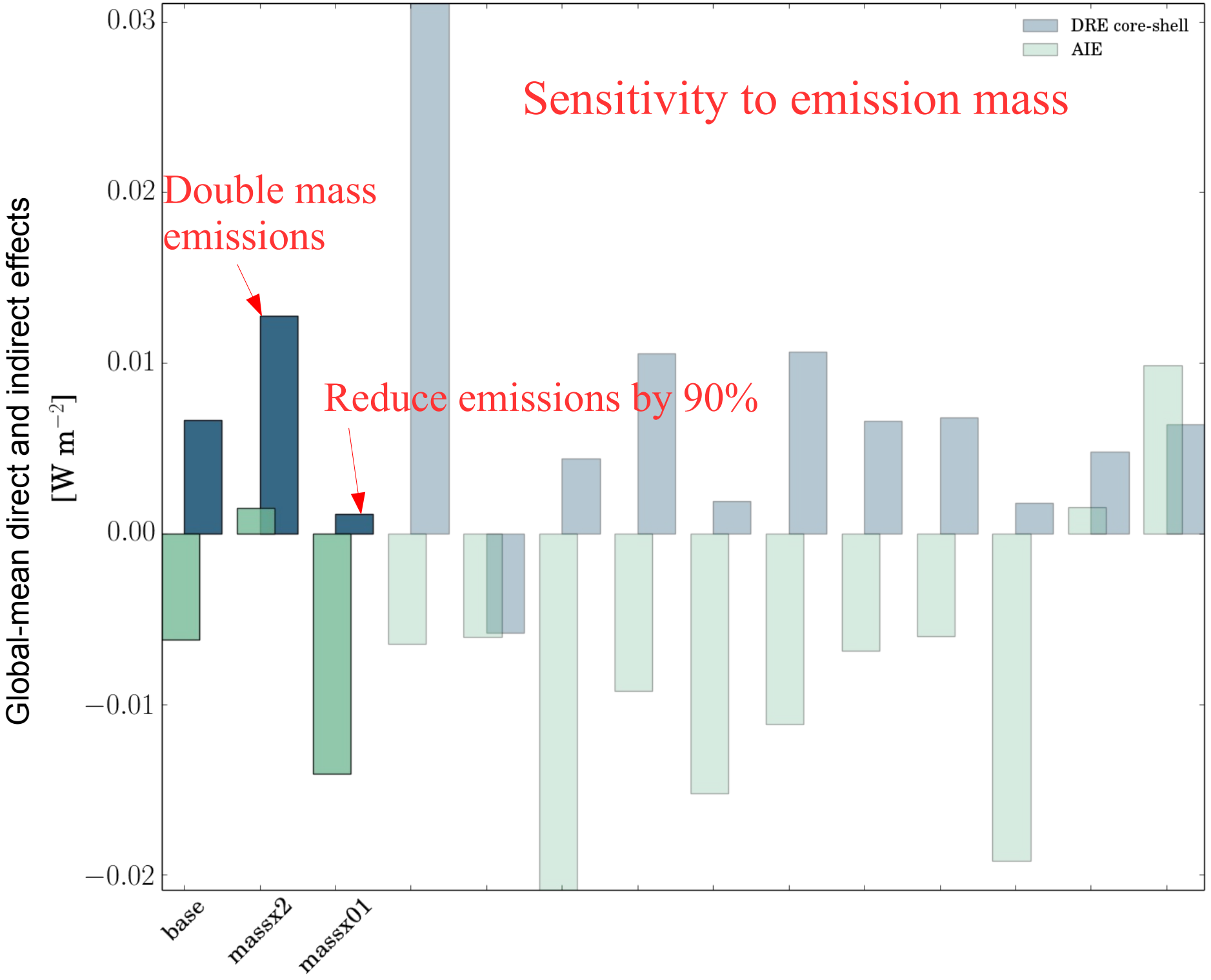
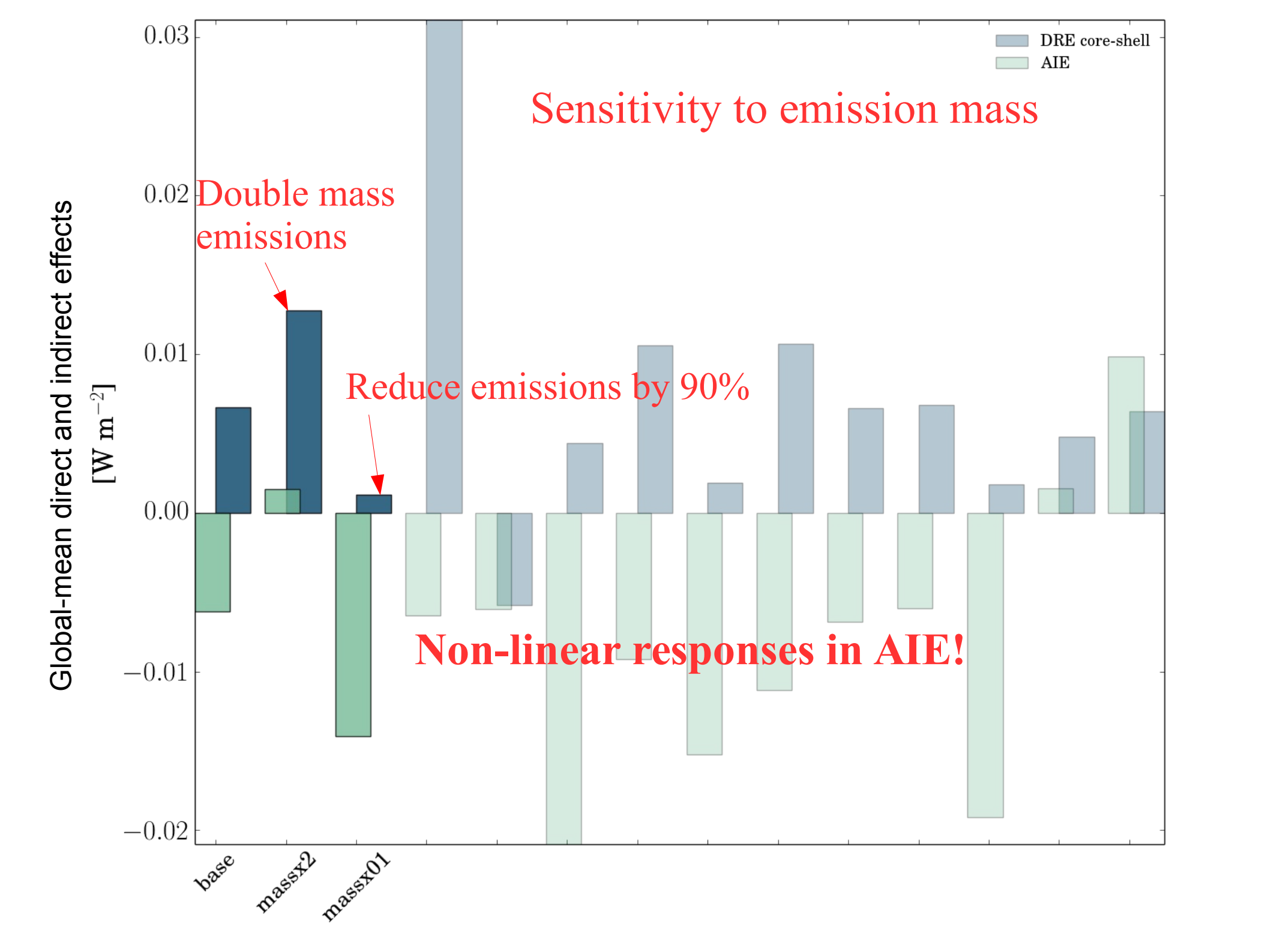
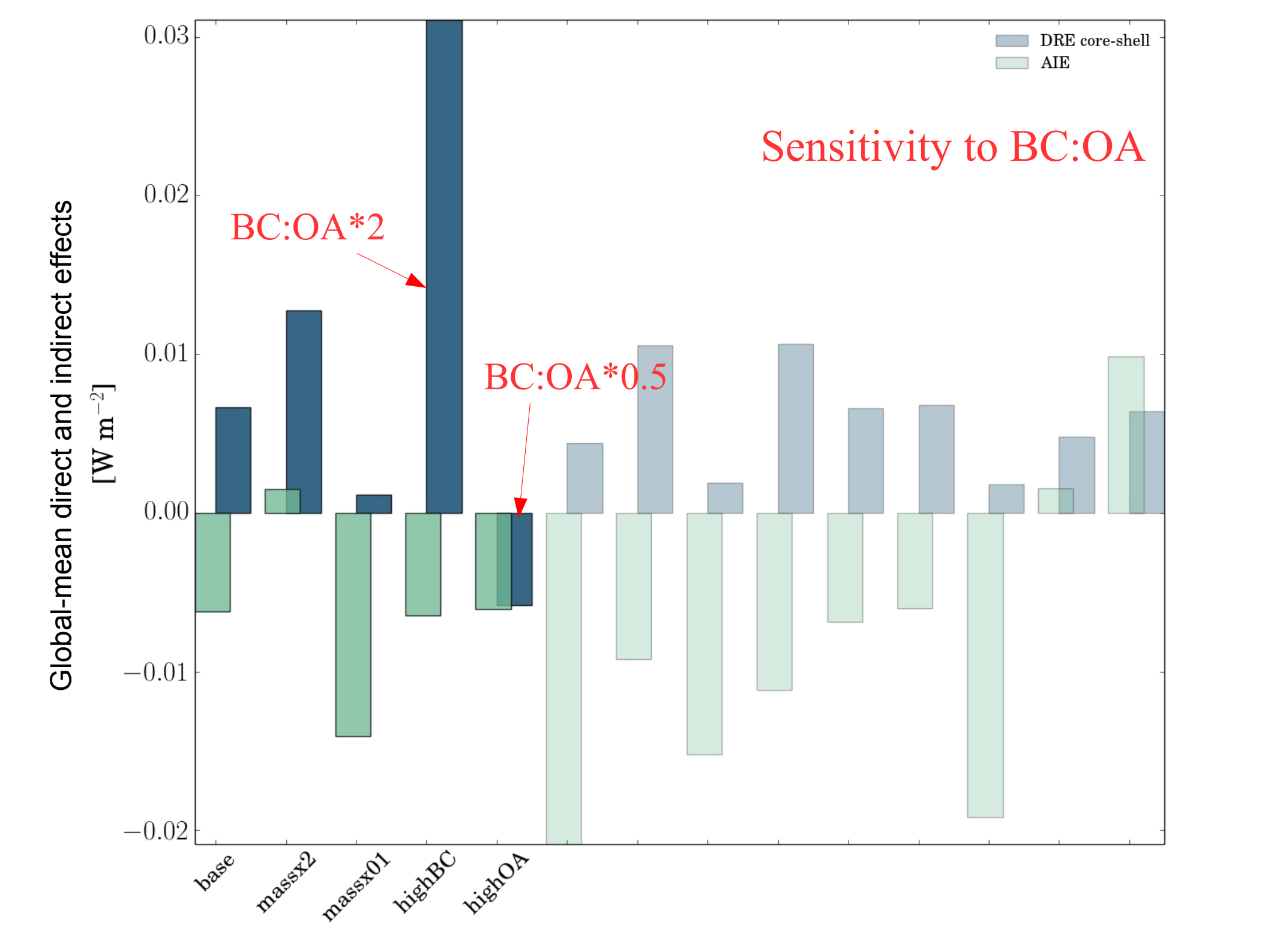


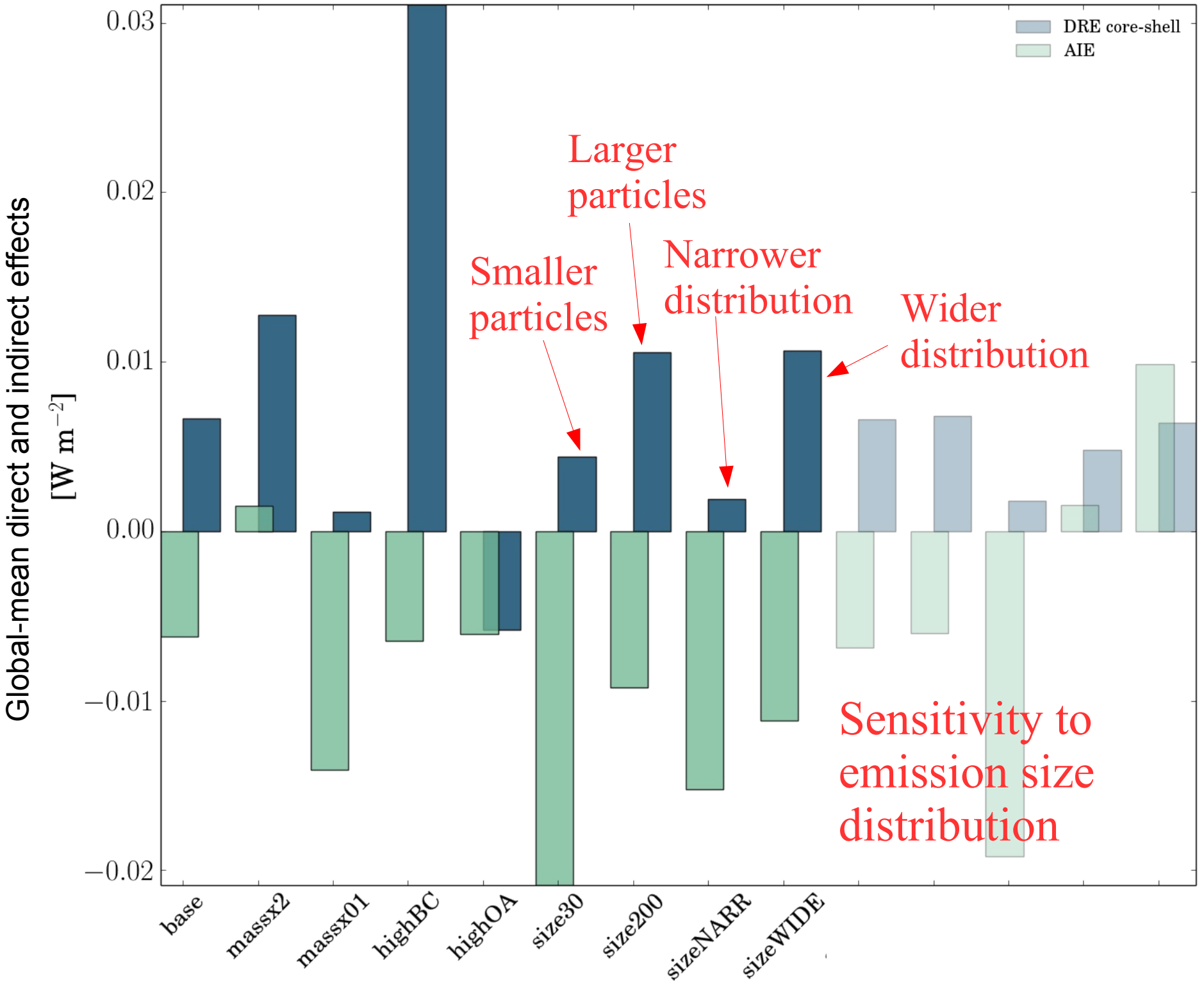
Sensitivity Simulations

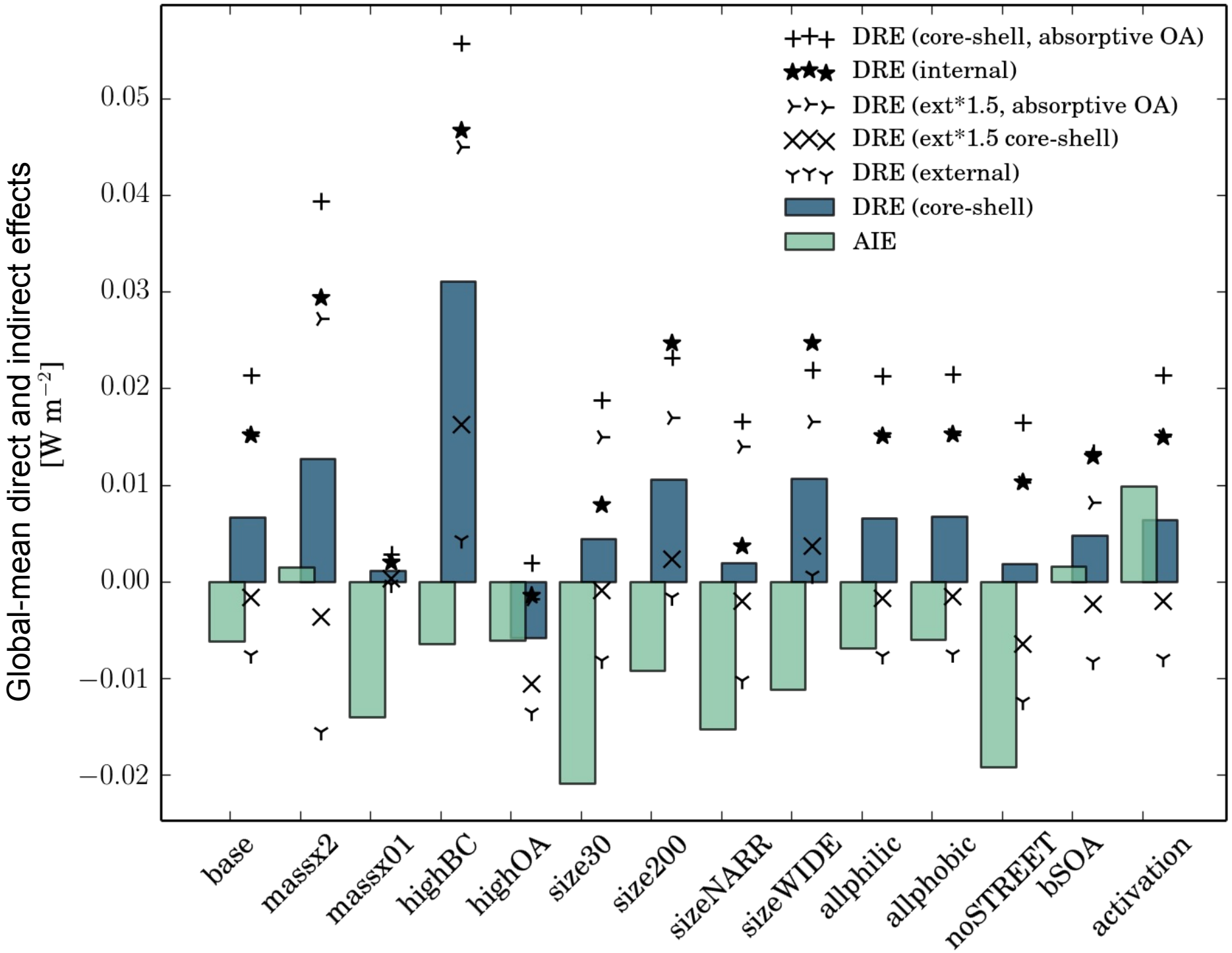

Global-mean direct and indirect effects
[W m^{-2}]
0.03
0.02
0.01
0.00
−0.01
−0.02
DRE core-shell
AIE
base

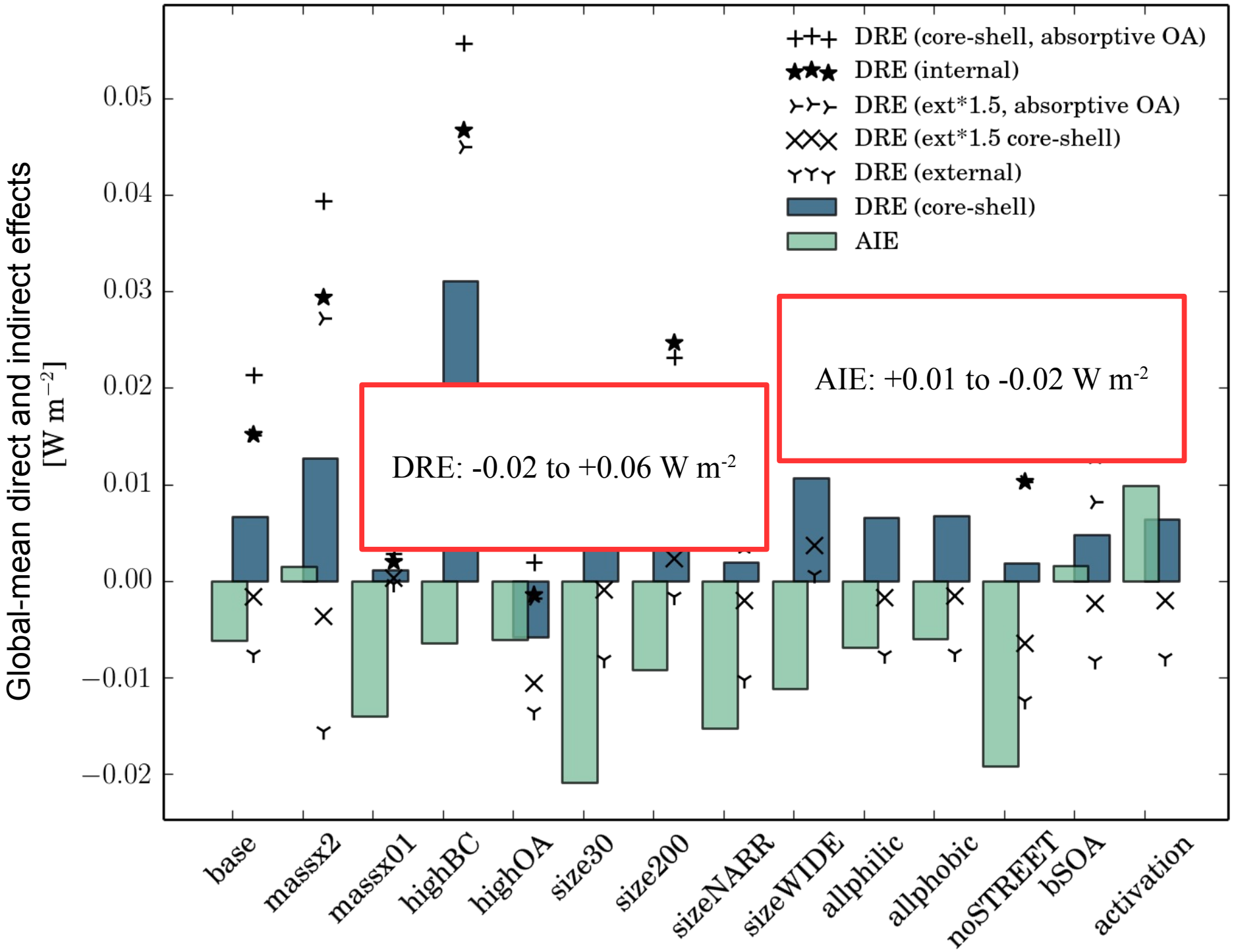

Sensitivity to emission mass
Double mass emissions
Reduce emissions by 90%
DRE core-shell
AIE
Global-mean direct and indirect effects
[W m^{-2}]
0.03
0.02
0.01
0.00
−0.01
−0.02
base
massx2
massx01


DRE core-shell
AIE
Sensitivity to emission mass
Double mass emissions
Reduce emissions by 90%
Non-linear responses in AIE!
Global-mean direct and indirect effects
[W m^{-2}]
0.03
0.02
0.01
0.00
−0.01
−0.02
base
massx2
massx01


Sensitivity to BC:OA
BC:OA*2
BC:OA*0.5
DRE core-shell
AIE
Global-mean direct and indirect effects
[W m^{-2}]
0.03
0.02
0.01
0.00
−0.01
−0.02
base
massx2
massx01
highBC
highOA


DRE core-shell
AIE
Global-mean direct and indirect effects
[W m^{-2}]
0.03
0.02
0.01
0.00
−0.01
−0.02
base
massx2
massx01
highBC
highOA
size30
size200
sizeNARR
sizeWIDE
Larger particles
Smaller particles
Narrower distribution
Wider distribution
Sensitivity to emission size distribution


Global-mean direct and indirect effects
[W m^{-2}]
0.05
0.04
0.03
0.02
0.01
0.00
−0.01
−0.02
DRE (core-shell, absorptive OA)
DRE (internal)
DRE (ext*1.5, absorptive OA)
DRE (ext*1.5 core-shell)
DRE (external)
DRE (core-shell)
AIE
base
massx2
massx01
highBC
highOA
size30
size200
sizeNARR
sizeWIDE
allphilic
allphobic
noSTREET
bSOA
activation


Global-mean direct and indirect effects
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DRE (internal)
DRE (ext*1.5, absorptive OA)
DRE (ext*1.5 core-shell)
DRE (external)
DRE (core-shell)
AIE
DRE: -0.02 to +0.06 W m^{-2}
AIE: +0.01 to -0.02 W m^{-2}
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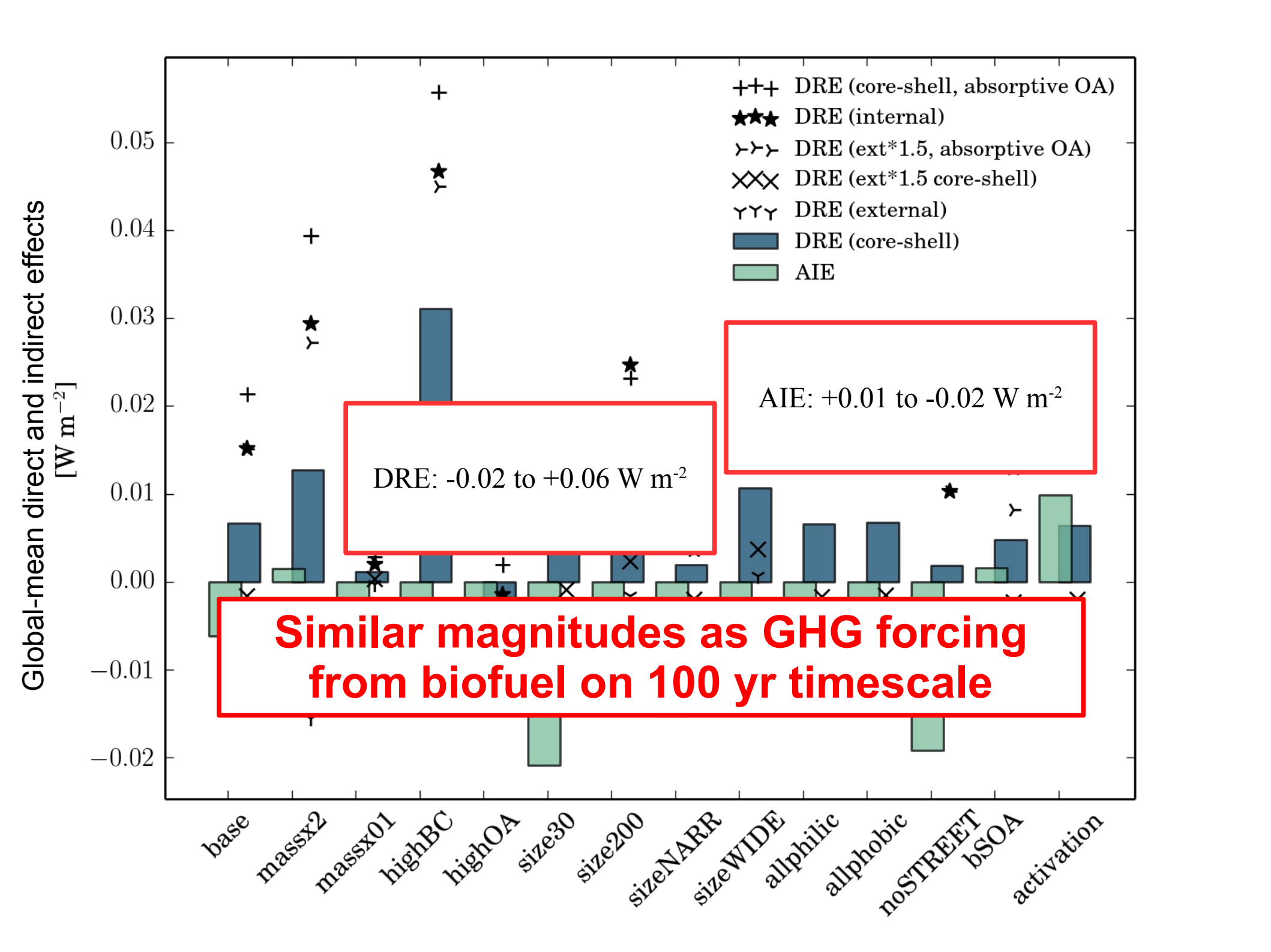
massx2
massx01
highBC
highOA
size30
size200
sizeNARR
sizeWIDE
allphilic
allphobic
noSTREET
bSOA
activation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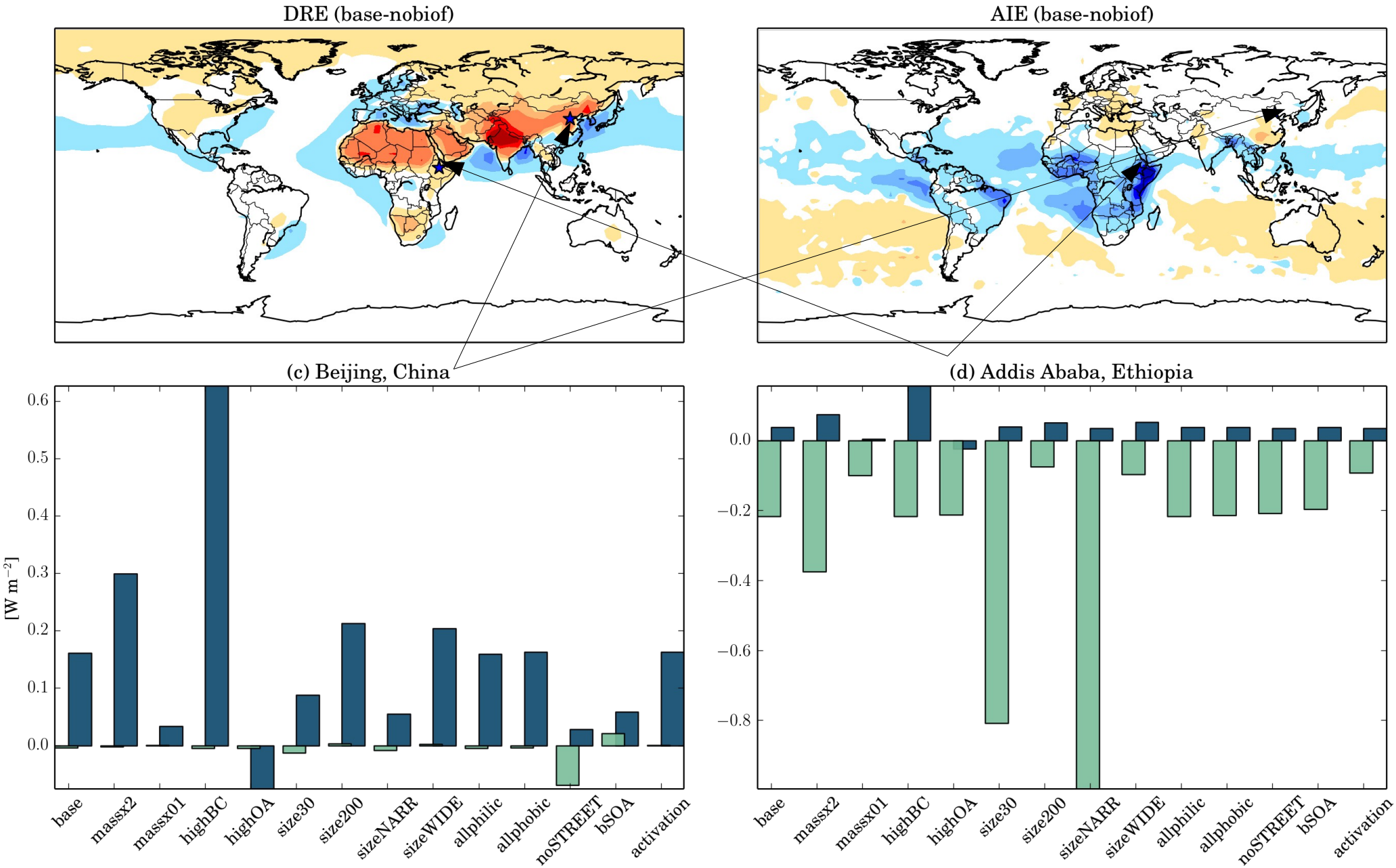
DRE (core-shell, absorptive OA)
DRE (internal)
DRE (ext*1.5, absorptive OA)
DRE (ext*1.5 core-shell)
DRE (external)
DRE (core-shell)
AIE
DRE: -0.02 to +0.06 W m^{-2}
AIE: +0.01 to -0.02 W m^{-2}
Similar magnitudes as GHG forcing from biofuel on 100 yr timescale
base
massx2
massx01
highBC
highOA
size30
size200
sizeNARR
sizeWIDE
allphilic
allphobic
noSTREET
bSOA
activation

Strong regional effects/uncertainties!



If you remember 1 thing from this presentation

- Uncertainties in aerosol-climate effects trump signal
- We don't even know the overall sign

Semi-related rant!

- Uncertainties in aerosol-climate effects trump signal
- We don't even know the overall sign
- Folks promoting BC controls as means of cooling climate are overconfident, in my opinion
  - (Unless can control BC w/o changing OC and size distributions)

Semi-related rant!

- Uncertainties in aerosol-climate effects trump signal
- We
- Folk ling climate are overconfident, in my opinion
  - (Unless can control BC w/o changing OC and size distributions)

Improve for health → Win
Improve for climate → Uncertain

Where modelers need help!

- Direct effect:
  - Total mass emissions
  - “Aged” optical properties (mixing, lensing, BrC)
  - BC:OC ratio
  - “Aged” size distributions
- Indirect effect
  - Total mass emissions
  - “Aged” size distributions