Using prescribed aerosol from MACv2-SP for assessing uncertainty in radiative forcing

Stephanie Fiedler

Contributions to MACv2.0-SP:

Bjorn Stevens, Thorsten Mauritsen, Stefan Kinne, Karsten Peters, Sebastian Rast, Jobst Müsse, Steven Smith

9th ICAP Meeting

Lille, 27 June 2017

Uncertainty in aerosol forcing

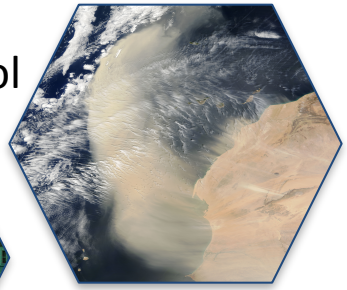
Atmospheric state

Natural aerosol

Surface albedo

Anthropogenic aerosol

Clouds and circulation



Potential sources for model uncertainty

in radiative forcing of anthropogenic aerosol

Uncertainty in aerosol forcing

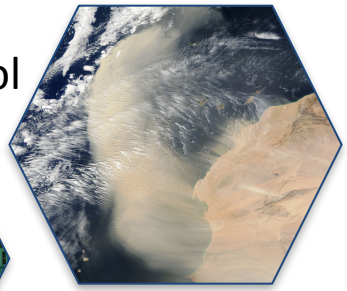
Atmospheric state

Natural aerosol

Surface albedo

Anthropogenic aerosol

Clouds and circulation



Potential sources for model uncertainty
in radiative forcing of anthropogenic aerosol

1. ?

2. ?

... ?

Need for **systematic assessment**
of their relative importance

Uncertainty in aerosol forcing

Atmospheric state

Natural aerosol

Surface albedo

Anthropogenic aerosol

Clouds and circulation

Potential sources for model uncertainty
in radiative forcing of anthropogenic aerosol

1. ? 2. ? ... ?

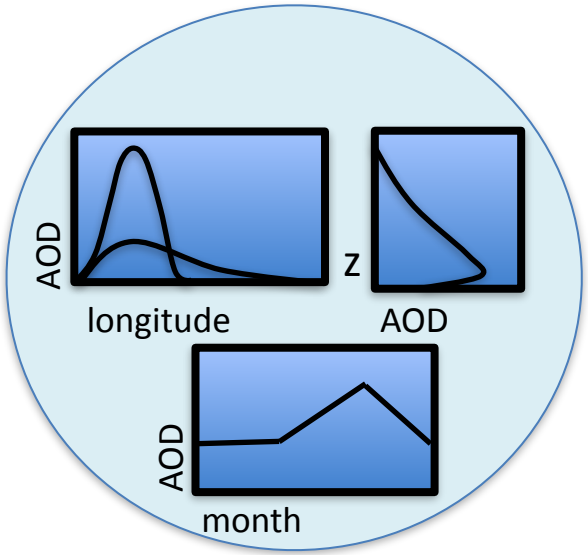
Need for **systematic assessment** of their relative importance

New parameterisation
MACv2.0-SP

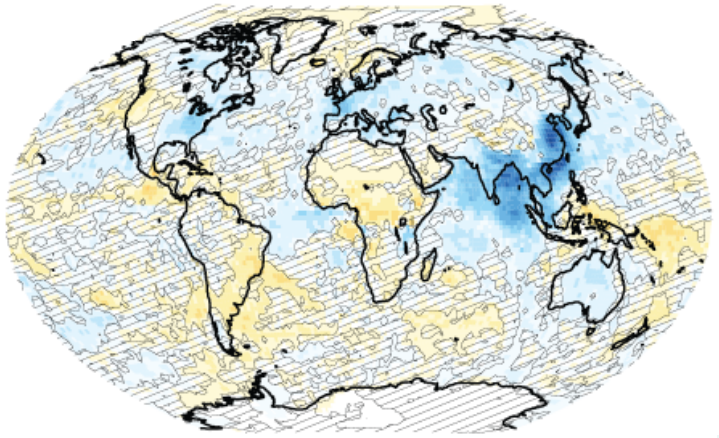
Prescribe same anthropogenic aerosol properties to study sensitivity

MACv2.0-SP as top-down approach to estimate radiative forcing associated with anthropogenic aerosol

1. **Introduction of MACv2.0-SP**
   A simplified parameterization.



2. **Application in MPI-M model**
   Radiative forcing estimates



INTRODUCTION OF MACv2.0-SP

A Simplified parameterization

Anthropogenic aerosol optical properties and associated change in cloud droplet number concentration

Constrained by observations

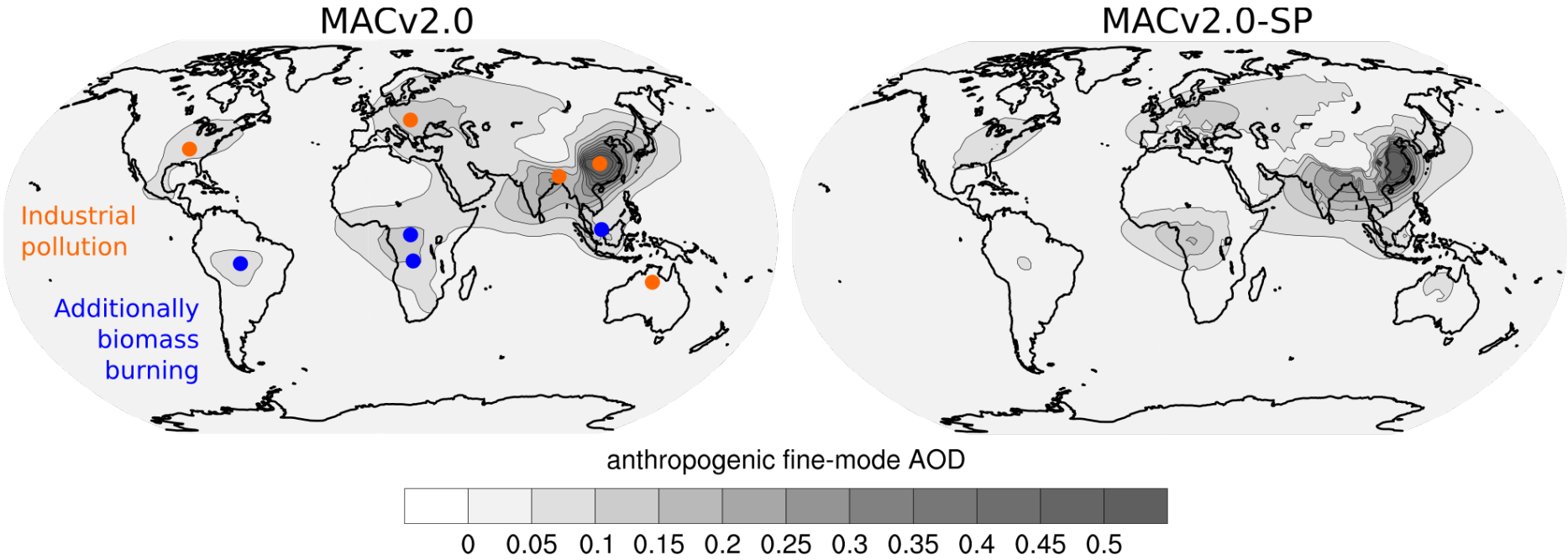
Computationally **fast**

Flexible application

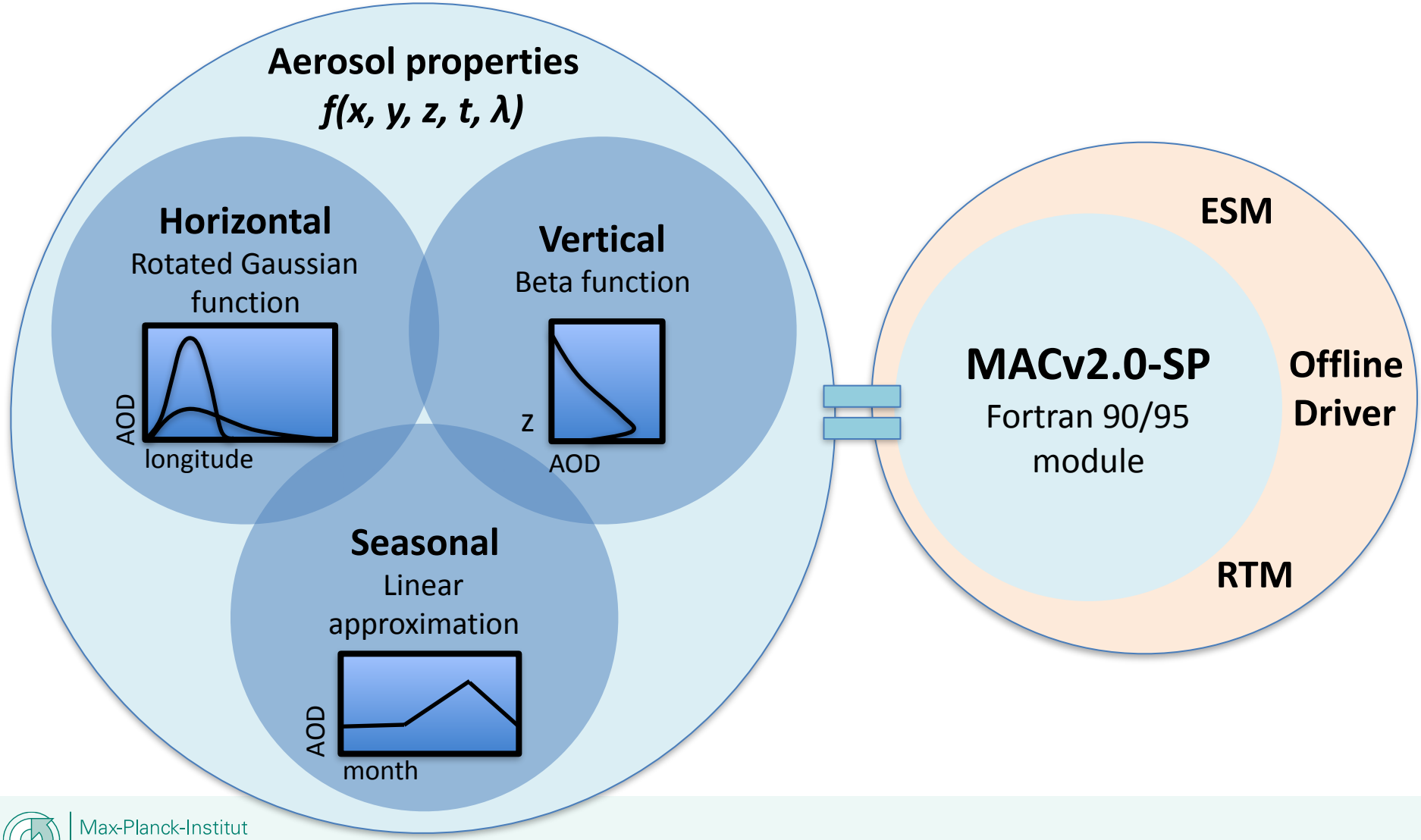
Easy to use

Constrained by observations

Annual mean anthropogenic AOD for present

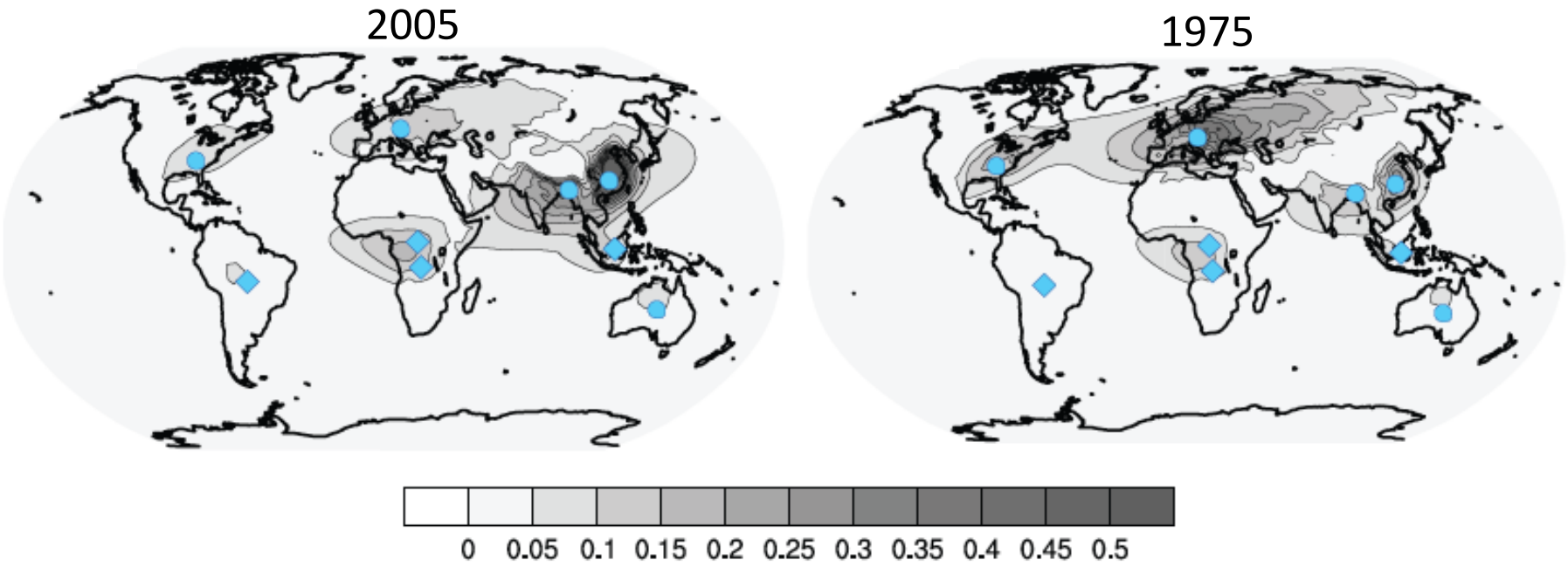


Fast and flexible design



Scaling for historical period

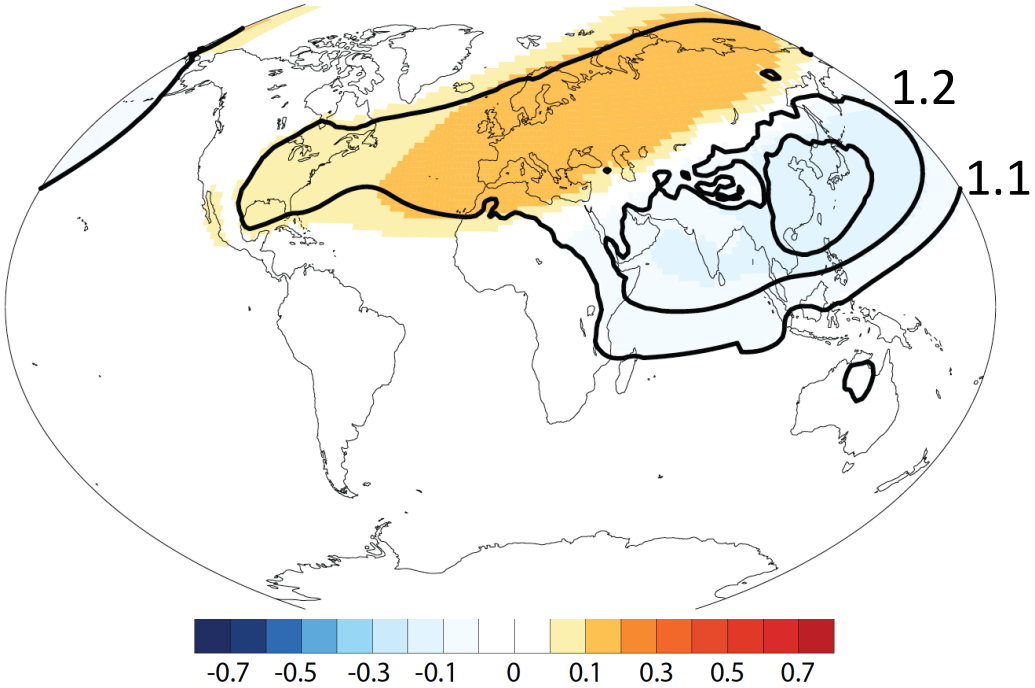
Annual mean anthropogenic aerosol optical depth



Fiedler et al. (2017, JAMES)

Parameterization of Twomey effect

Annual mean difference in η_N for 1975 - 2005



$$\eta_N = 1 + \frac{dN}{N} = \frac{ln\left[1000\ \left(\tau_{\mathrm{a}} + \tau_{\mathrm{bg}}\right) + 1\right]}{ln\left[1000\ \tau_{\mathrm{bg}} + 1\right]}$$

Multiplied with CDNC to be used in radiation calculation

Fiedler et al. (2017, JAMES)

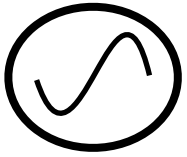
APPLICATION OF MACV2.0-SP IN ECHAM6.3

The sensitivity of forcing estimates.

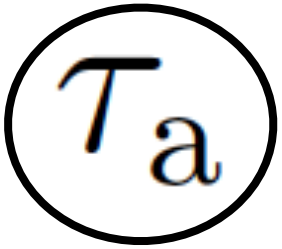
τ_a Spatial patterns of anthropogenic aerosol

η_N Formulation of Twomey effect

τ_{bg} Strength of Twomey effect / Natural aerosol background



Natural atmospheric variability



MACv2.0-SP in ECHAM6.3

PRESENT-DAY EFFECTIVE RADIATIVE FORCING

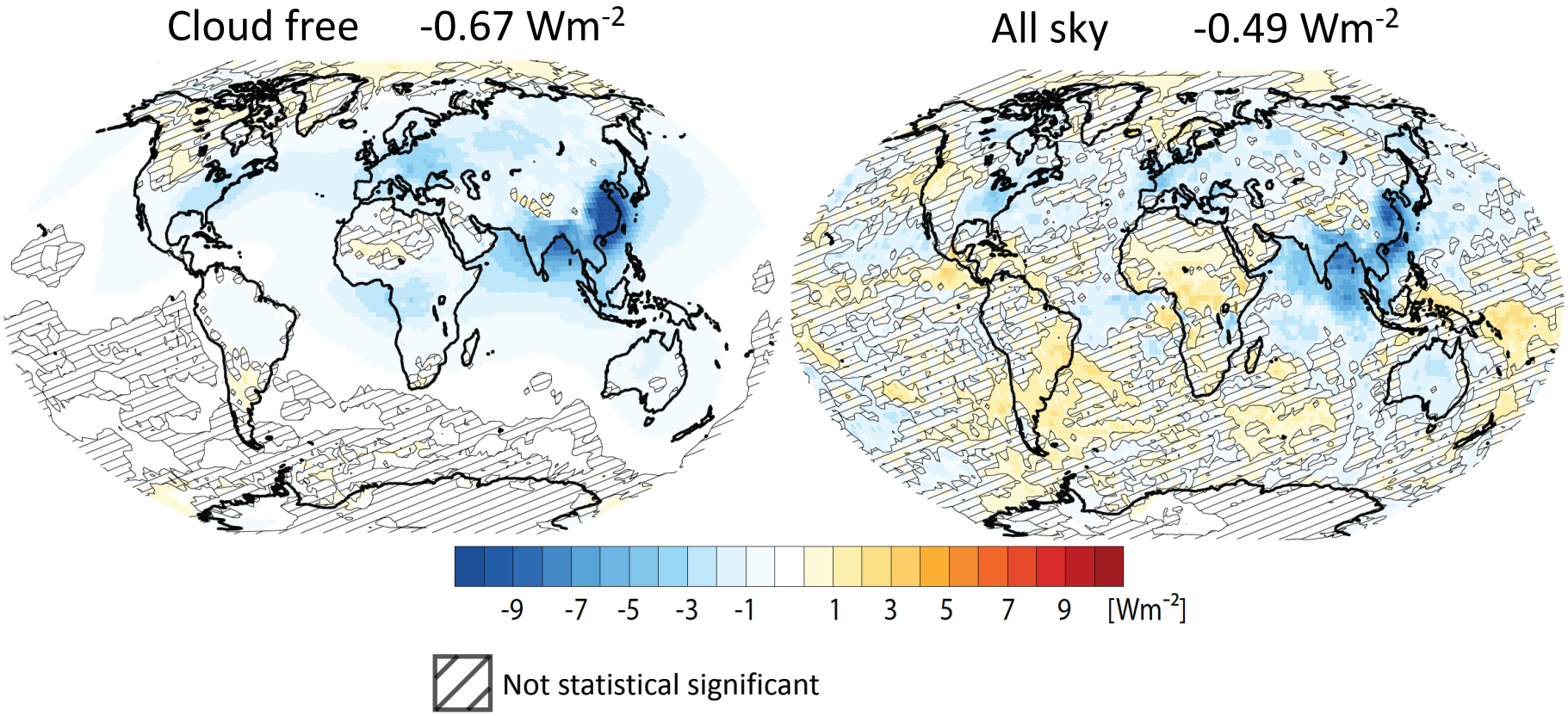
Ensembles of AMIP simulations for 2001-2010:

- pre-industrial aerosol (natural only), 6 members
- present-day aerosol (natural plus anthropogenic), 3 members

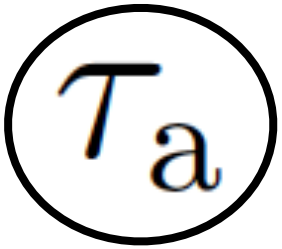
Present-day effective radiative forcing

Annual ensemble average for present-day

(SW, TOA, 180 years)



Fiedler et al. (2017, JAMES)



MACv2.0-SP in ECHAM6.3

DOES THE AEROSOL PATTERN AFFECT THE GLOBAL MEAN FORCING?

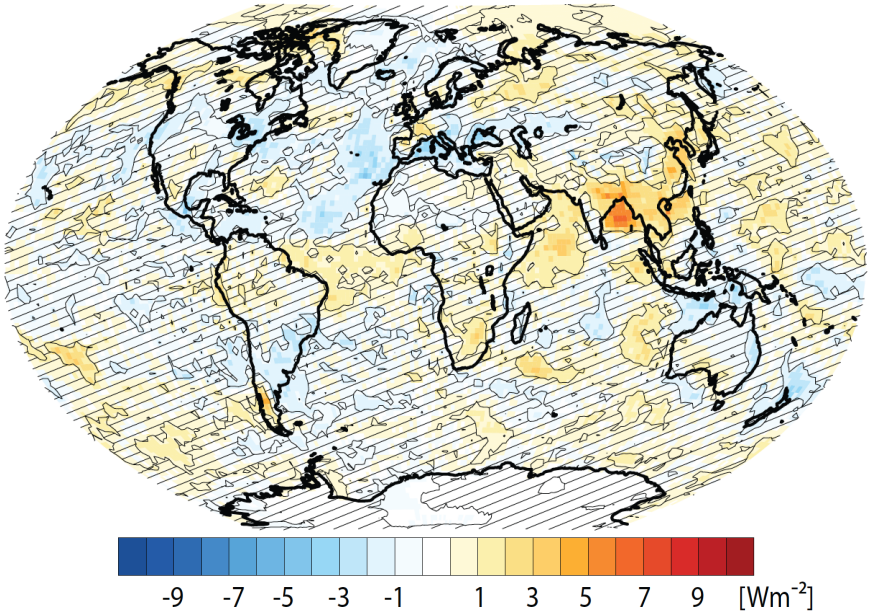
Ensembles of AMIP simulations for 2001-2010:

- pre-industrial aerosol (natural only), 6 members
- present-day aerosol (natural plus anthropogenic), 3 members
- mid-1970s aerosol (natural plus anthropogenic), 3 members

Sensitivity of ERF to spatial pattern of anthropogenic aerosol

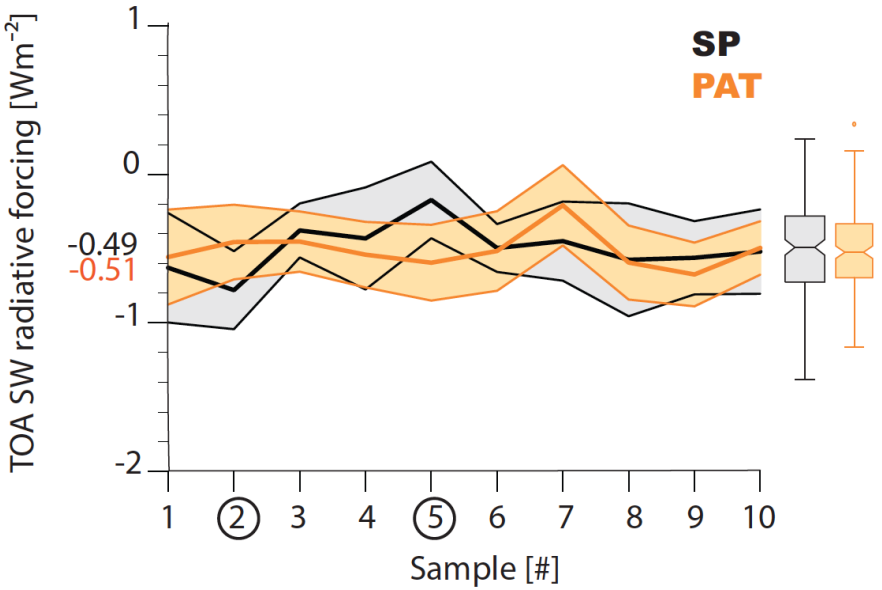
Annual ensemble averaged all-sky ERF (SW, TOA)

PAT (mid-1970s) - SP (present-day)
(180 years)



Not statistical significant

Sub-sampling global means
(18 years each)



Statistical significant

Fiedler et al. (2017, JAMES)

MACv2.0-SP in ECHAM6.3

HOW COULD THE AEROSOL PATTERN AFFECT GLOBAL MEAN FORCING?

Ensembles of AMIP simulations for 2001-2010:

- pre-industrial aerosol (natural only), 6 members
- present-day aerosol (natural plus anthropogenic), 3 members
- mid-1970s aerosol (natural plus anthropogenic), 3 members
- alternative parameterisation of Twomey effect, 3 members

Formulation of Twomey effect

QTE

$$\frac{\exp\left[5 + 0.3\ ln\left(\tau_{\mathrm{a}} + \tau_{\mathrm{bg}}\right)\right]}{\exp\left[5 + 0.3\ ln\ \tau_{\mathrm{bg}}\right]}$$

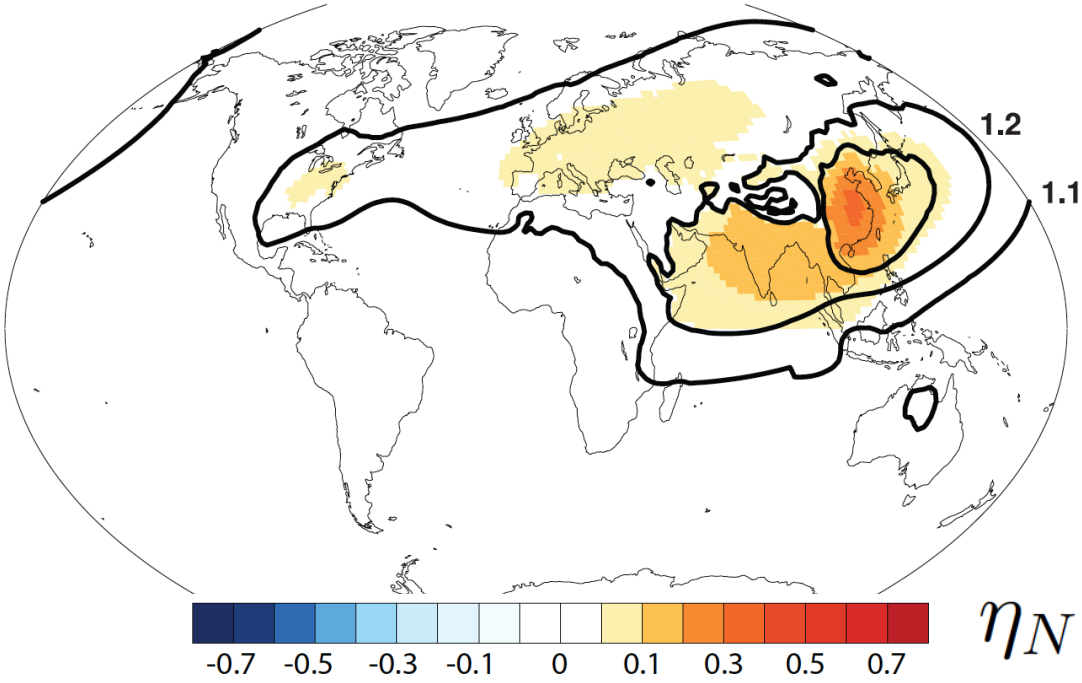
following Quaas et al. (2006)

SP

$$\frac{ln\left[1000\ \left(\tau_{\mathrm{a}} + \tau_{\mathrm{bg}}\right) + 1\right]}{ln\left[1000\ \tau_{\mathrm{bg}} + 1\right]}$$

Stevens et al. (2017), Fiedler et al. (2017)

QTE – SP

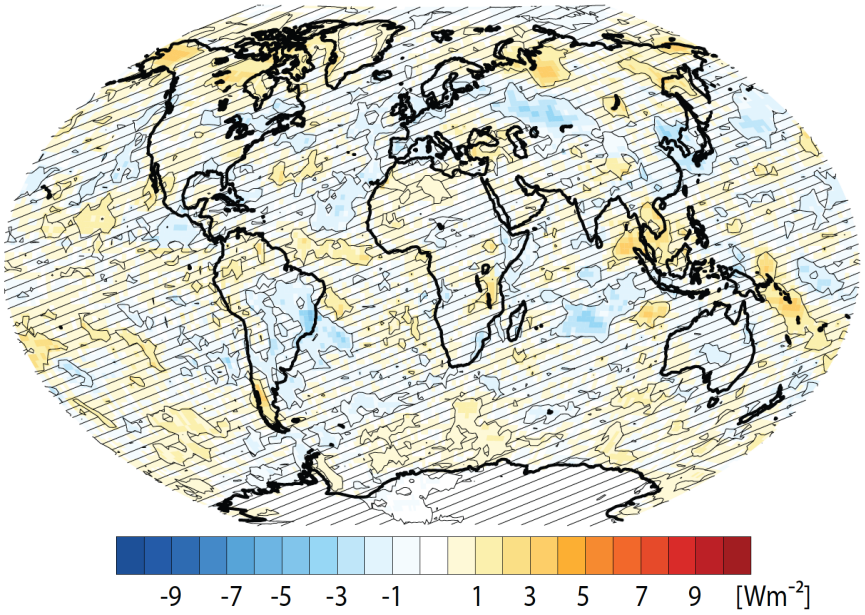


Fiedler et al. (2017, JAMES)

Sensitivity to formulation of Twomey effect

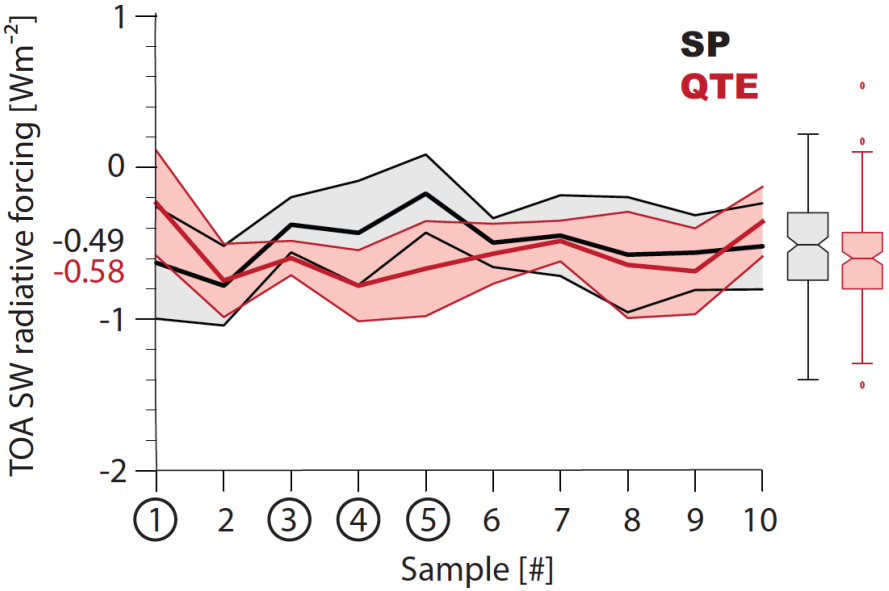
Annual ensemble averaged all-sky ERF (SW, TOA)

QTE - SP (present-day)
(180 years)



Not statistical significant

Sub-sampling global means
(18 years each)



Statistical significant

Fiedler et al. (2017, JAMES)

MACv2.0-SP in ECHAM6.3

HOW COULD THE AEROSOL PATTERN AFFECT GLOBAL MEAN FORCING?

Ensembles of AMIP simulations for 2001-2010:

- pre-industrial aerosol (natural only), 6 members
- present-day aerosol (natural plus anthropogenic), 3 members
- mid-1970s aerosol (natural plus anthropogenic), 3 members
- induce stronger Twomey effect, 3 members

Decreased natural background aerosol

$$\tau_{bg} = \tau_{bg,plumes} + \tau_{bg,global}$$

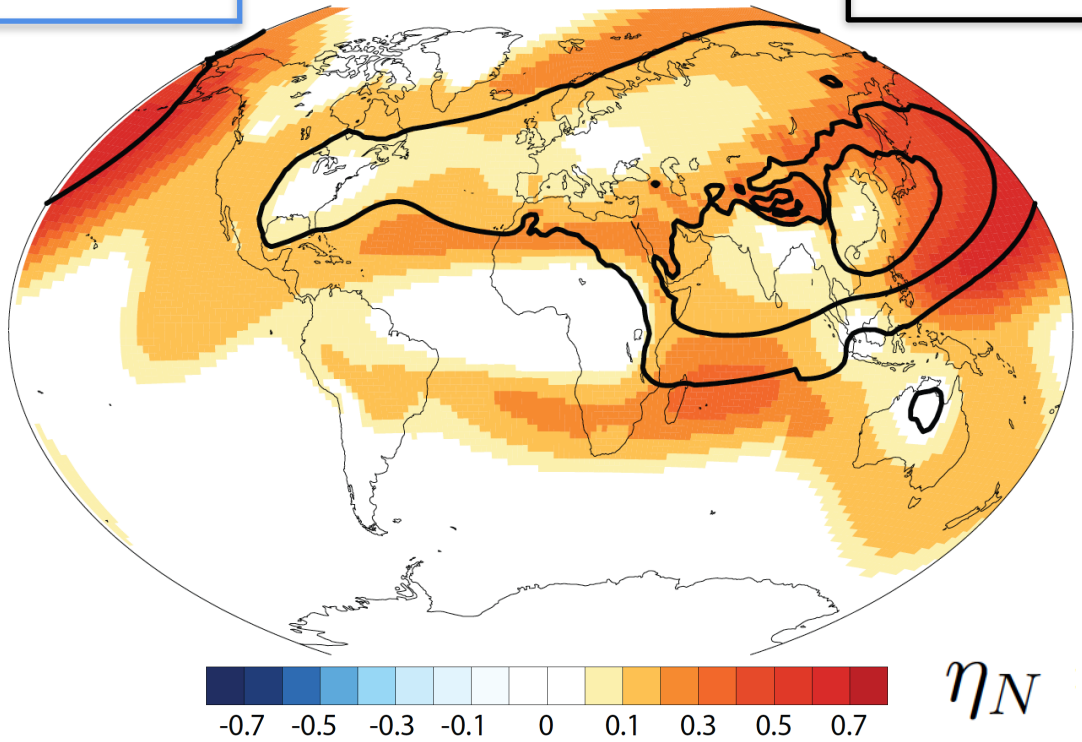
LBG

$\tau_{bg,global} = 0.002$

SP

$\tau_{bg,global} = 0.02$

LBG – SP

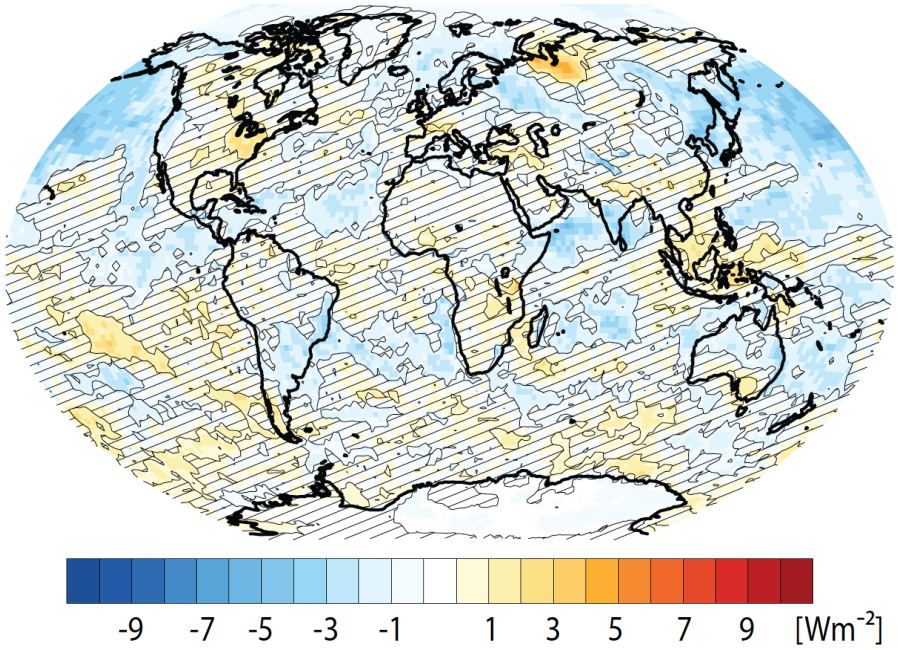


Fiedler et al. (2017, JAMES)

τ_{bg} Sensitivity to natural background in Twomey effect

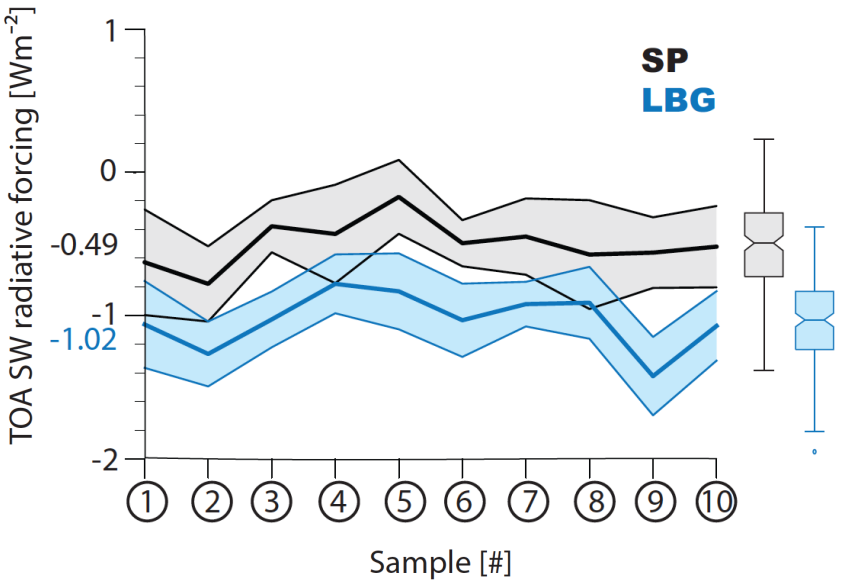
Annual ensemble averaged all-sky ERF (SW, TOA)

LBG - SP (present-day)
(180 years)



Not statistical significant

Sub-sampling global means
(18 years each)

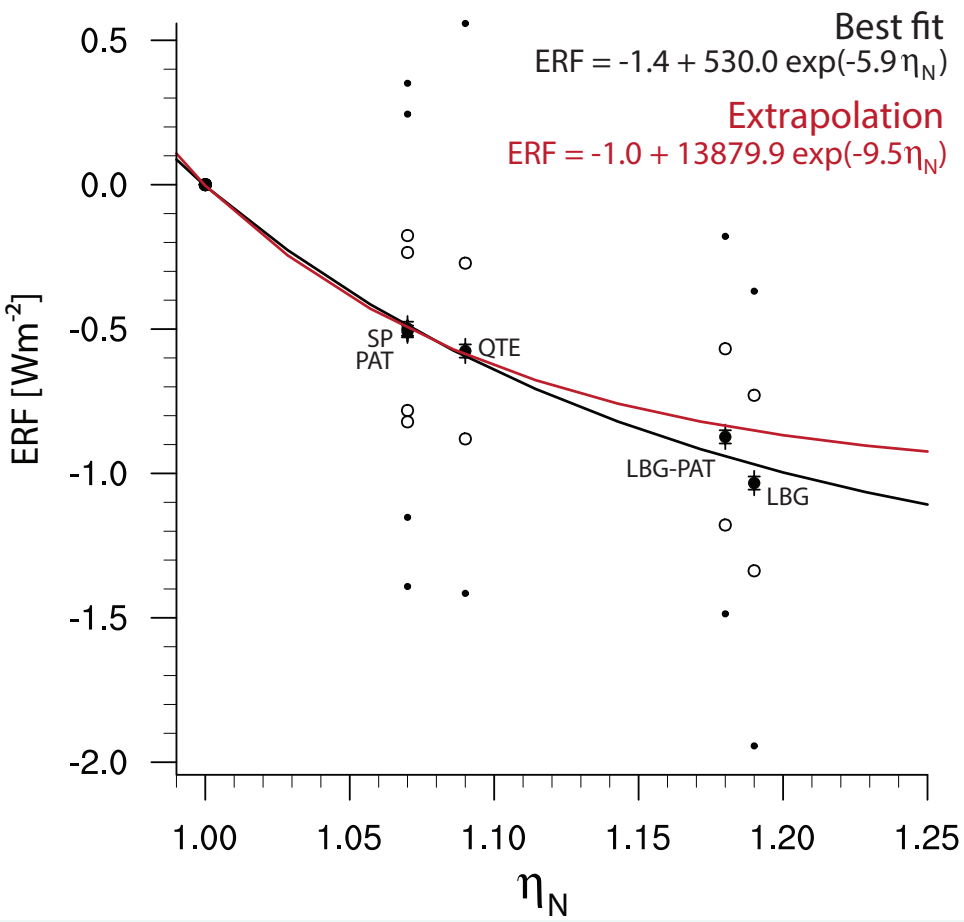


Statistical significant

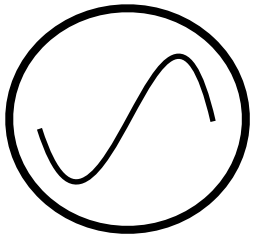
Fiedler et al. (2017, JAMES)

In a nutshell

180-years of ERF estimates with ECHAM6.3 AMIP ensembles and MACv2.0-SP aerosol



Pattern has **small effect** on global mean all-sky ERF, unless we mimic a strong Twomey effect



Atmospheric **variability** has a **strong** impact on ERF estimate

Fiedler et al. (2017, JAMES)

Outlook and discussion

- Future model inter-comparison works with MACv2-SP:

  RFMIP (CMIP6) and within EU project BACCHUS

- More information:

  Stevens et al. (2017, GMD): Technical description
  Fiedler et al. (2017, JAMES): Sensitivity of forcing

Outlook and discussion

- Future model inter-comparison works with MACv2-SP:

  RFMIP (CMIP6) and within EU project BACCHUS

- More information:

  Stevens et al. (2017, GMD): Technical description
  Fiedler et al. (2017, JAMES): Sensitivity of forcing

- Discussion item:

  Inter-comparison of ICAP models using
  MACv2-SP anthropogenic aerosol?

Feedback and questions welcome.

(stephanie.fiedler@mpimet.mpg.de)

Thanks.