AEROSOL
global distributions

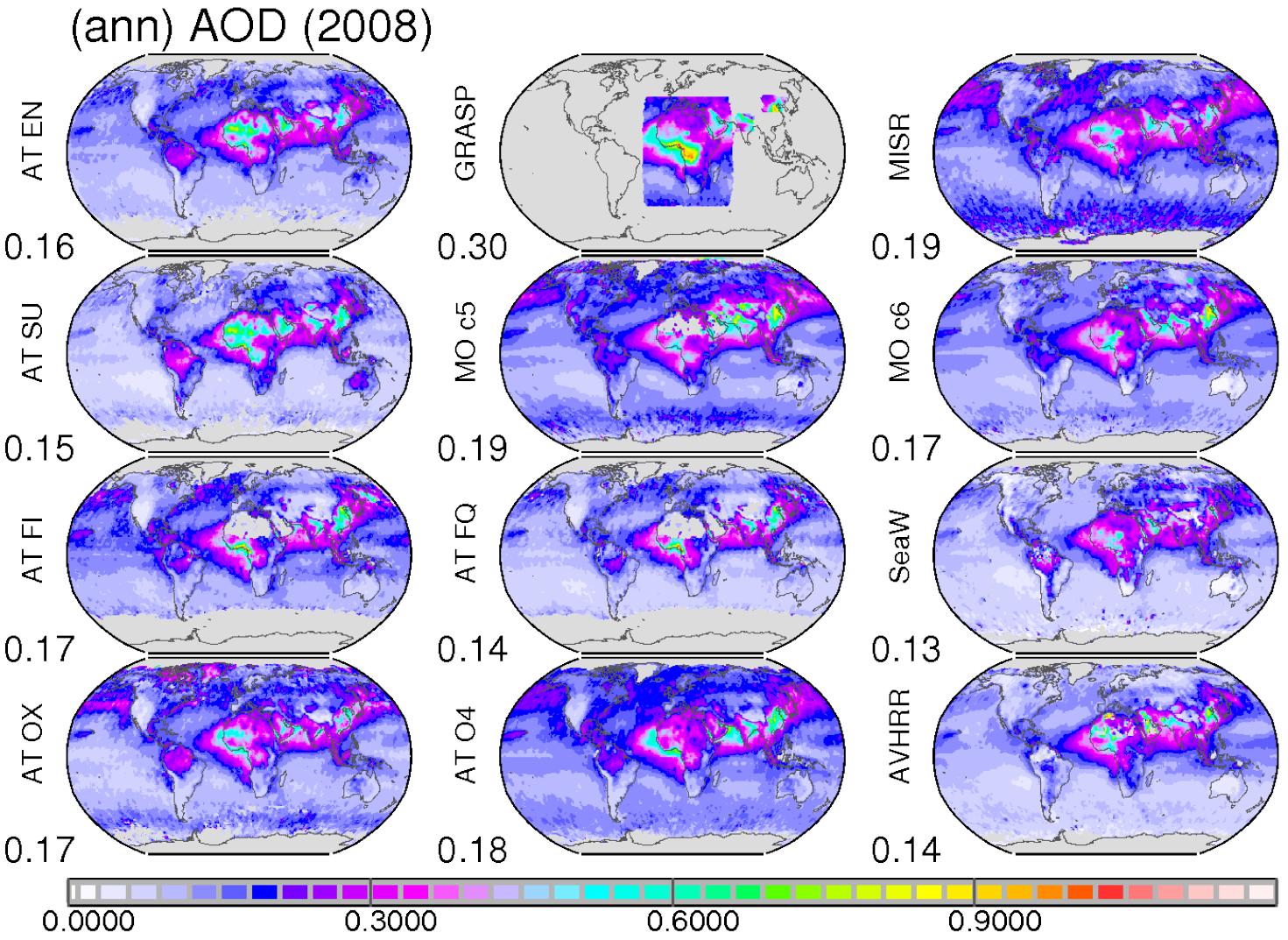
Stefan Kinne, *MPI-Meteorology*

maps

- to address globally varying (atmospheric) properties I (we all) like MAPS
  - more informative than global averages
- Bill & Co has done this for clouds …
  - so this could also be done for aerosol
- Bill & Co used satellite data and smart models
  - and this also has been done for aerosol

AOD – diversity in satellite remote sensing

same year … but different answers, coverage, models



what we really want

- complete coverage
  - satellite retrievals fail at times (e.g. over snow)
- address not just aerosol amount (e.g. AOD), but also aerosol size (FMF) and absorption (AAOD)
  - satellite retrieval mainly address AOD, FMF at best over oceans, and absorption at best in a qualitative sense (e.g. UV aerosol index)
- high accuracy & property consistencies
  - satellite retrievals make different assumptions and are handicapped by a poor background
- **MAC** (now version 2) **!**

MAC v2

Max-Planck-Aerosol Climatology

- **use**
  - for mid-visible aerosol properties
    - » AOD, AAOD, FMF, Angstrom
  - high accuracy of AERONET / MAN
  - spatial context from modeling

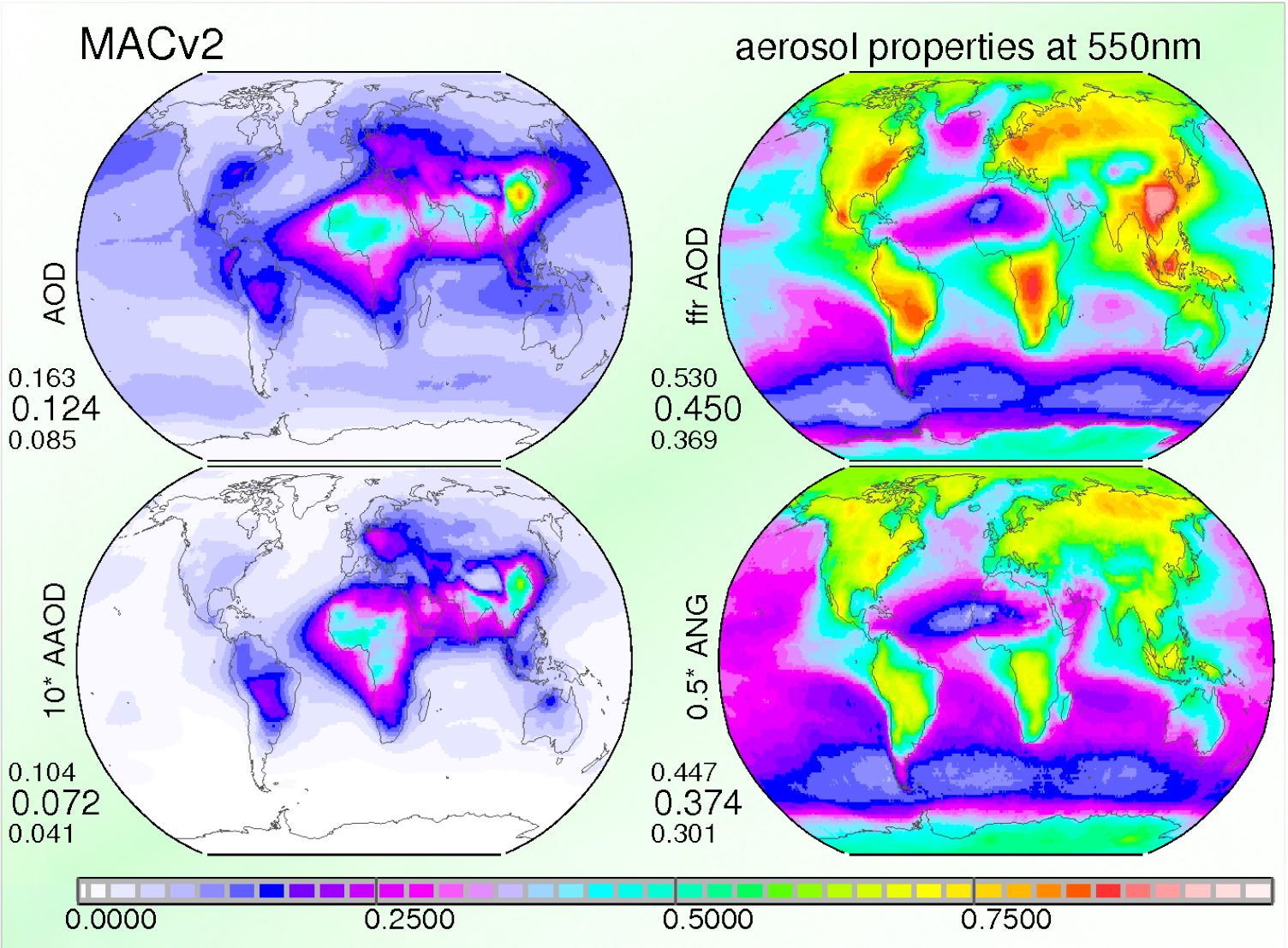
AerChemMIP AeroSAT CCMI AeroCom

- **merge multi-year monthly statistics**
  - 1x1 lat/lon, monthly maps
    - for spectral dep properties (fine & coarse)
      - » AOD, SSA, g
    - for vertical distribution (fine & coarse)
    - for anthrop. fraction of fine (function of time)

MACv2

AOD

AAOD
(10 times)



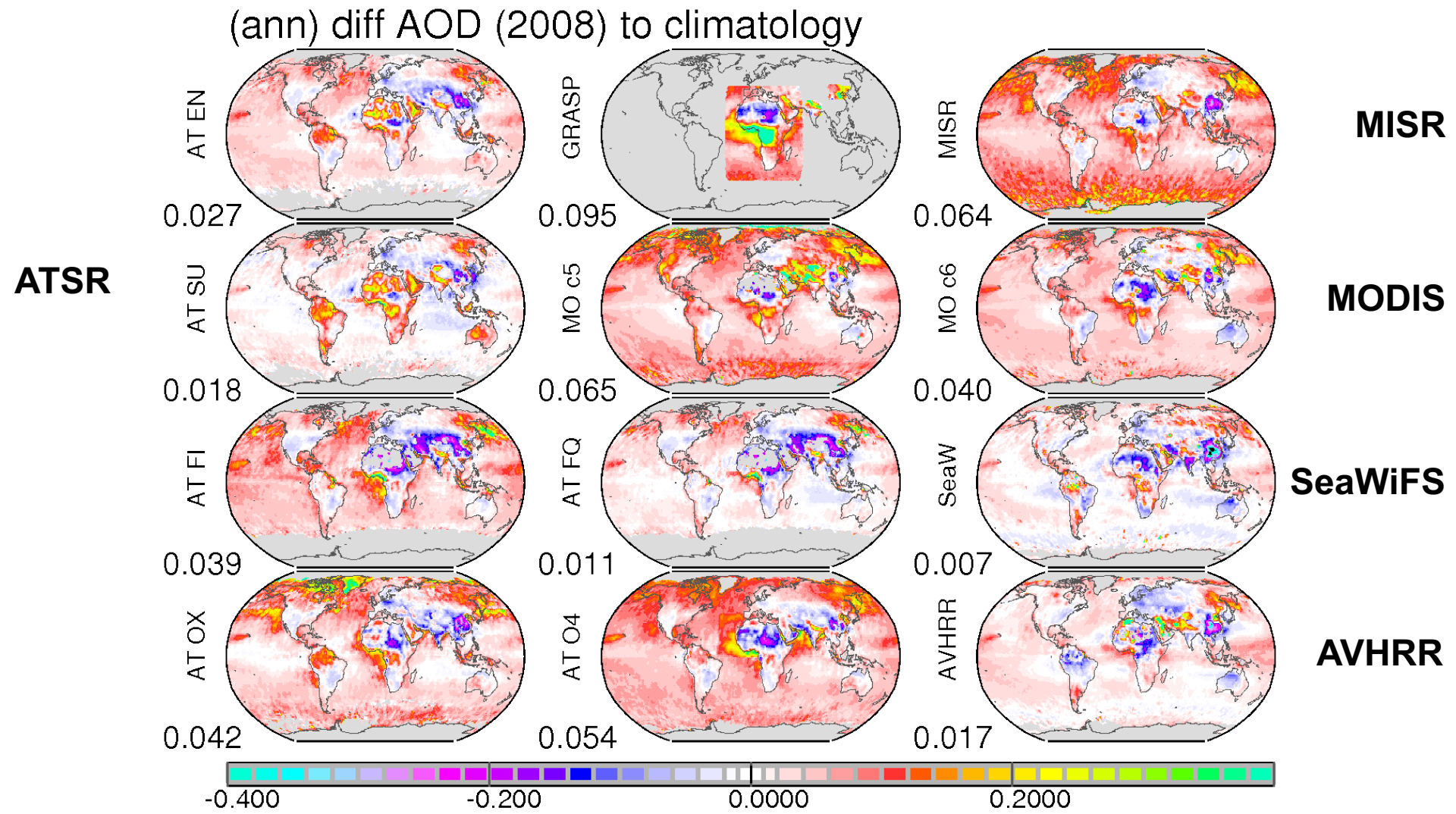
FMF

ANG
(div by 2)

annual
means

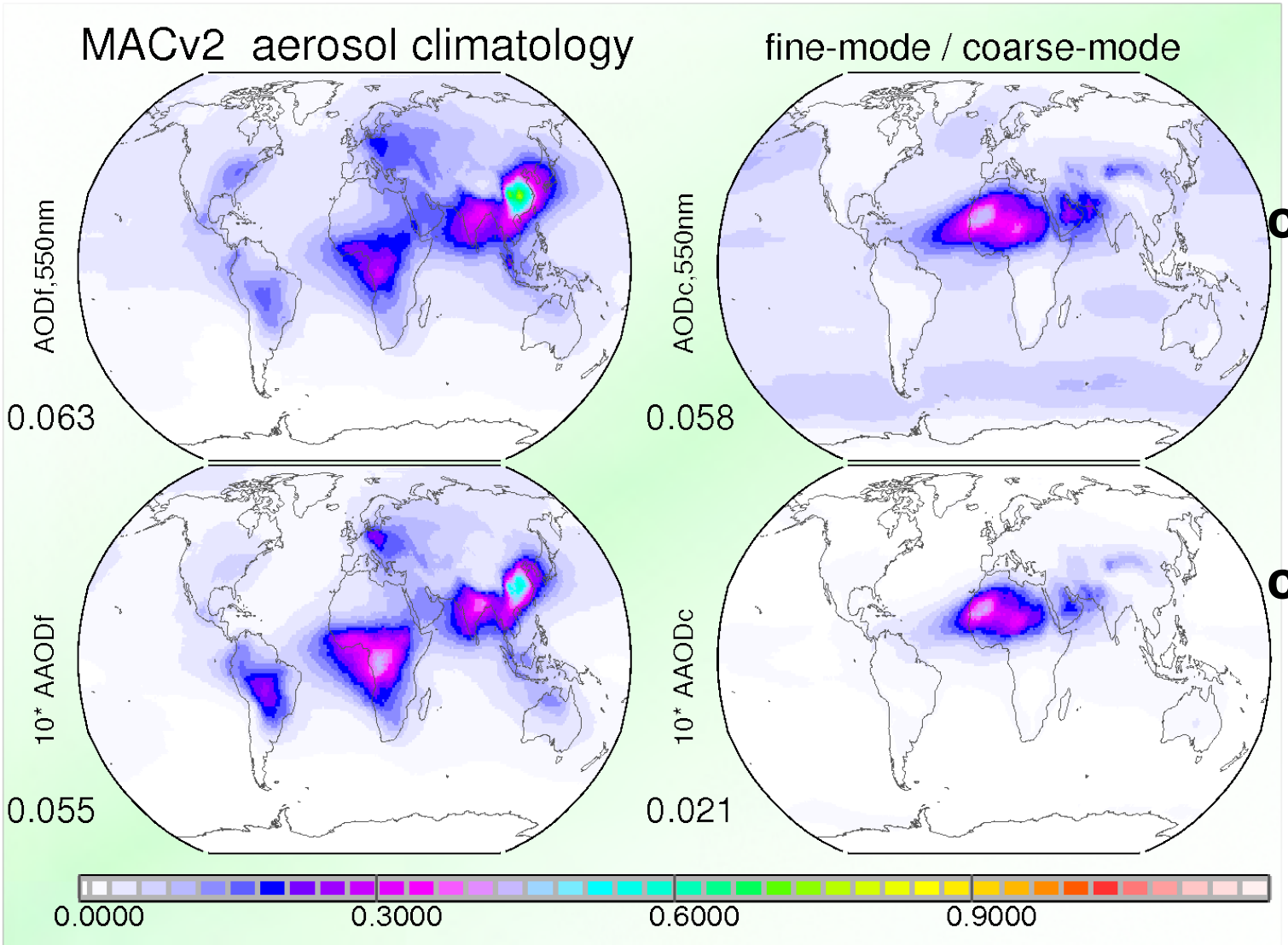
satellite AOD biases

if we believe MACv2 *(not specific for year 2008 though)*



MACv2 - AOD and AAOD by size-mode

fine-mode **coarse mode**



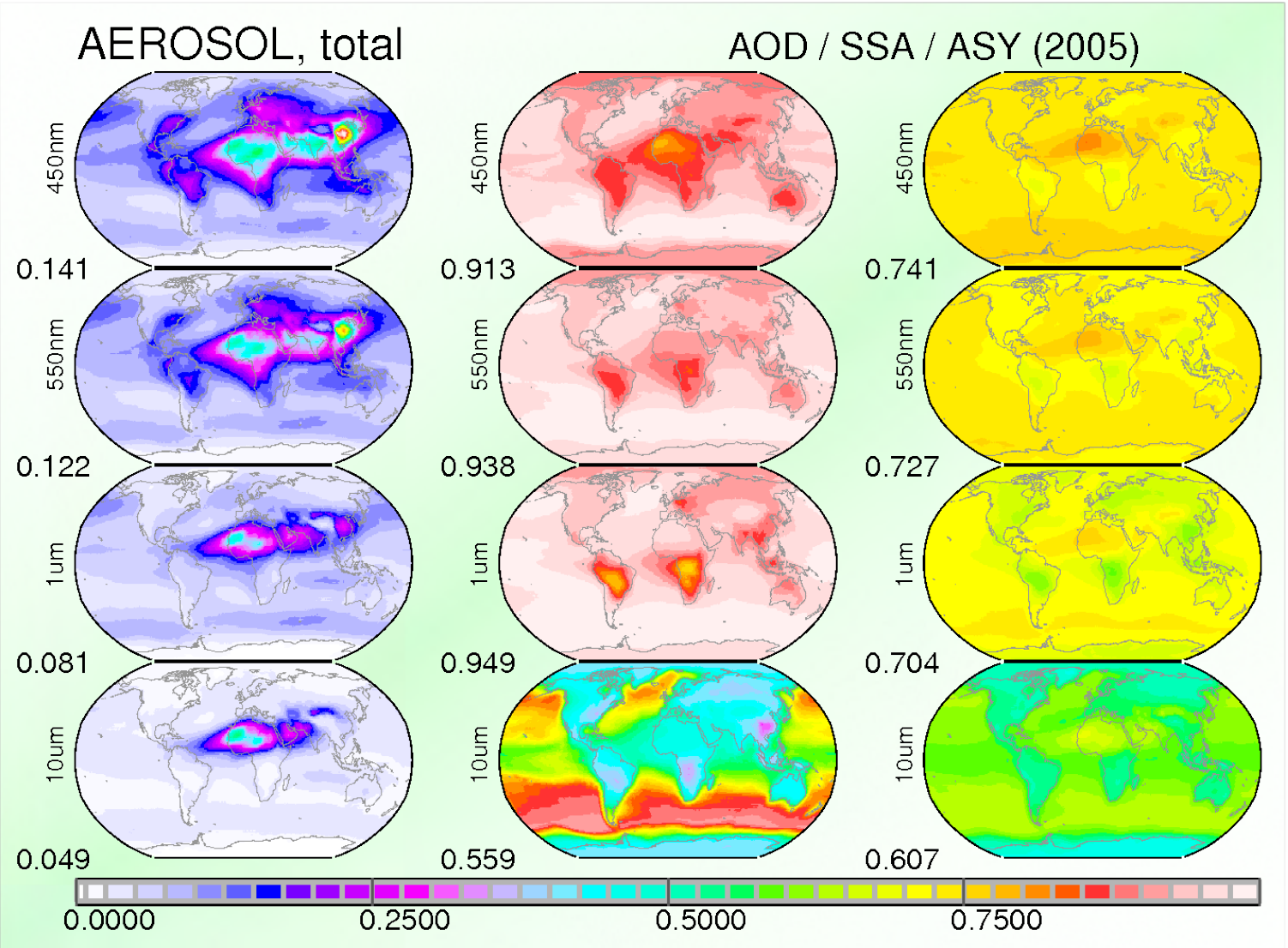
fine AOD 50%

coarse AOD 50%

fine AAOD (10 times) 70%

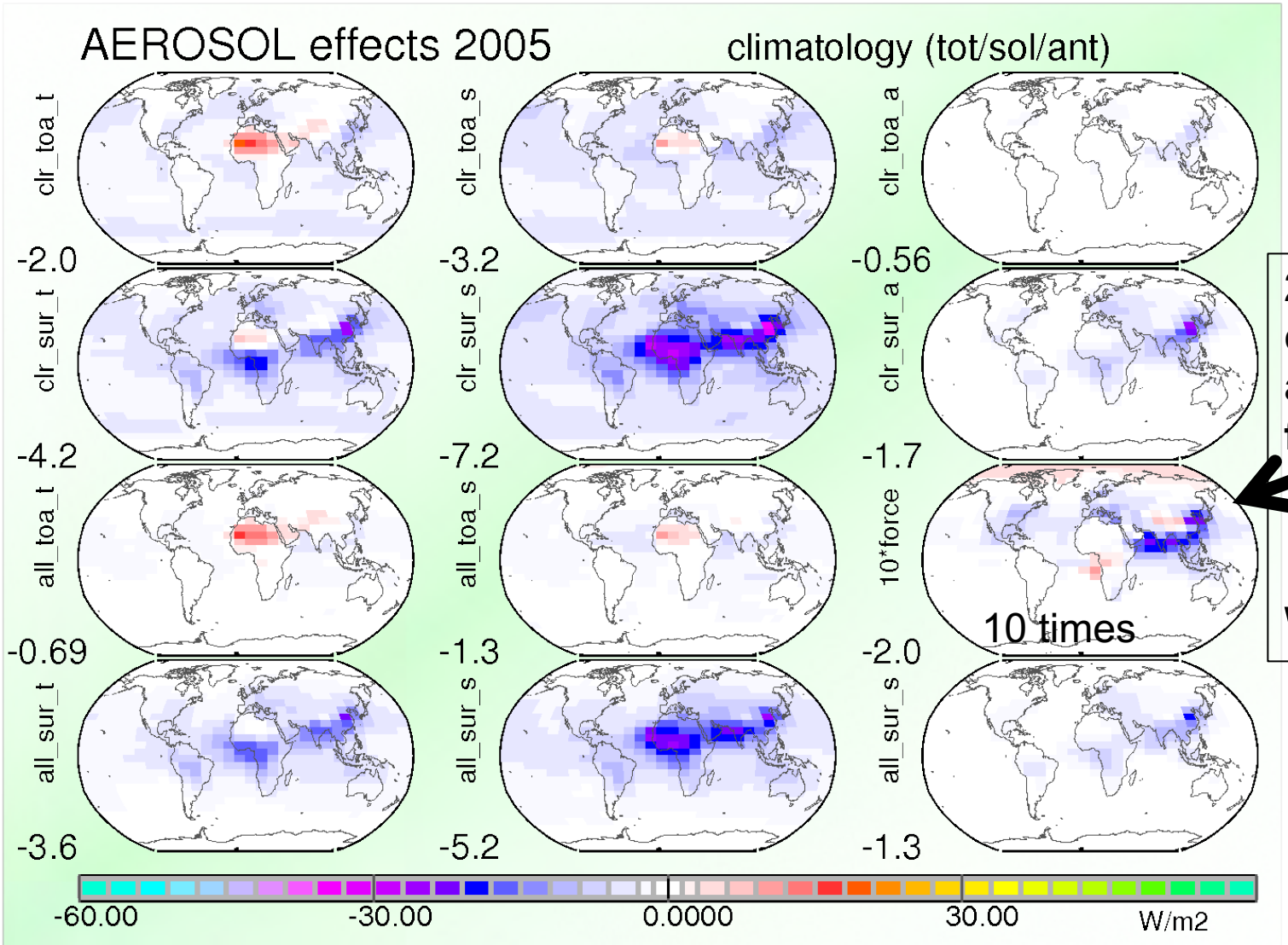
coarse AAOD (10 times) 30%

Radiative impacts – here we are



direct radiative effects - 2005

solar +IR **solar only** **anthropogenic**



clr-sky TOA

clr-sky surf

all-sky TOA

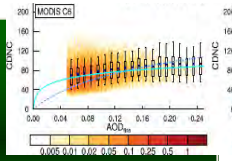
all-sky surf

2005 direct anthrop forcing

-0.2 W/m2

indirect forcing ?

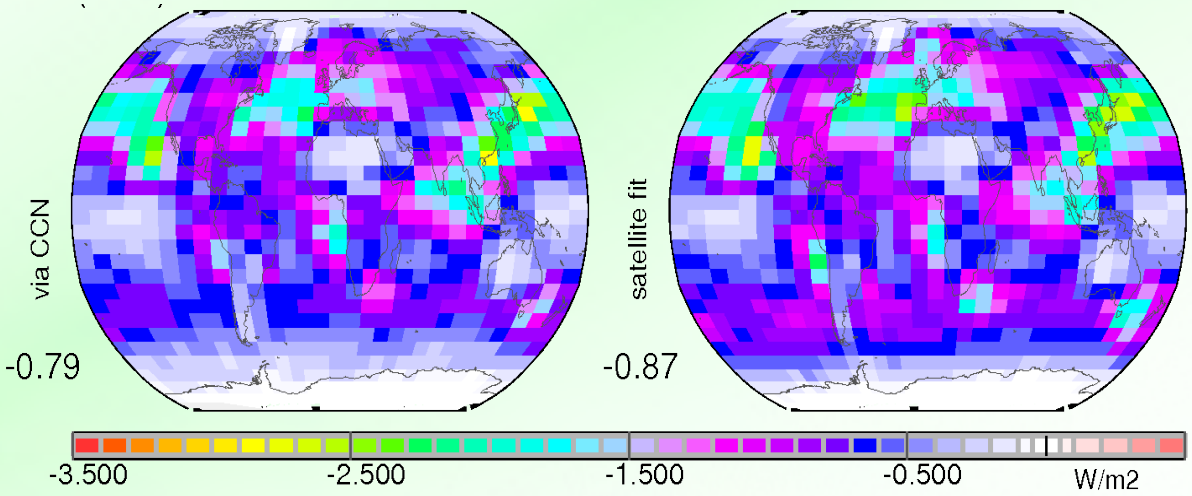
we tried it 2 ways … almost identical result



- **assuming that the Twomey effect only matters**
  - **more CCN from anthr. aerosol → more CDNC in water clouds → more cloud solar reflection**
  - **existing CDNC (natural) background matters**

complex: use a vertical distribution, assume SS (.1%), determine CCN

simple: use AODf CDNC relations of MODIS and ATSR retrievals

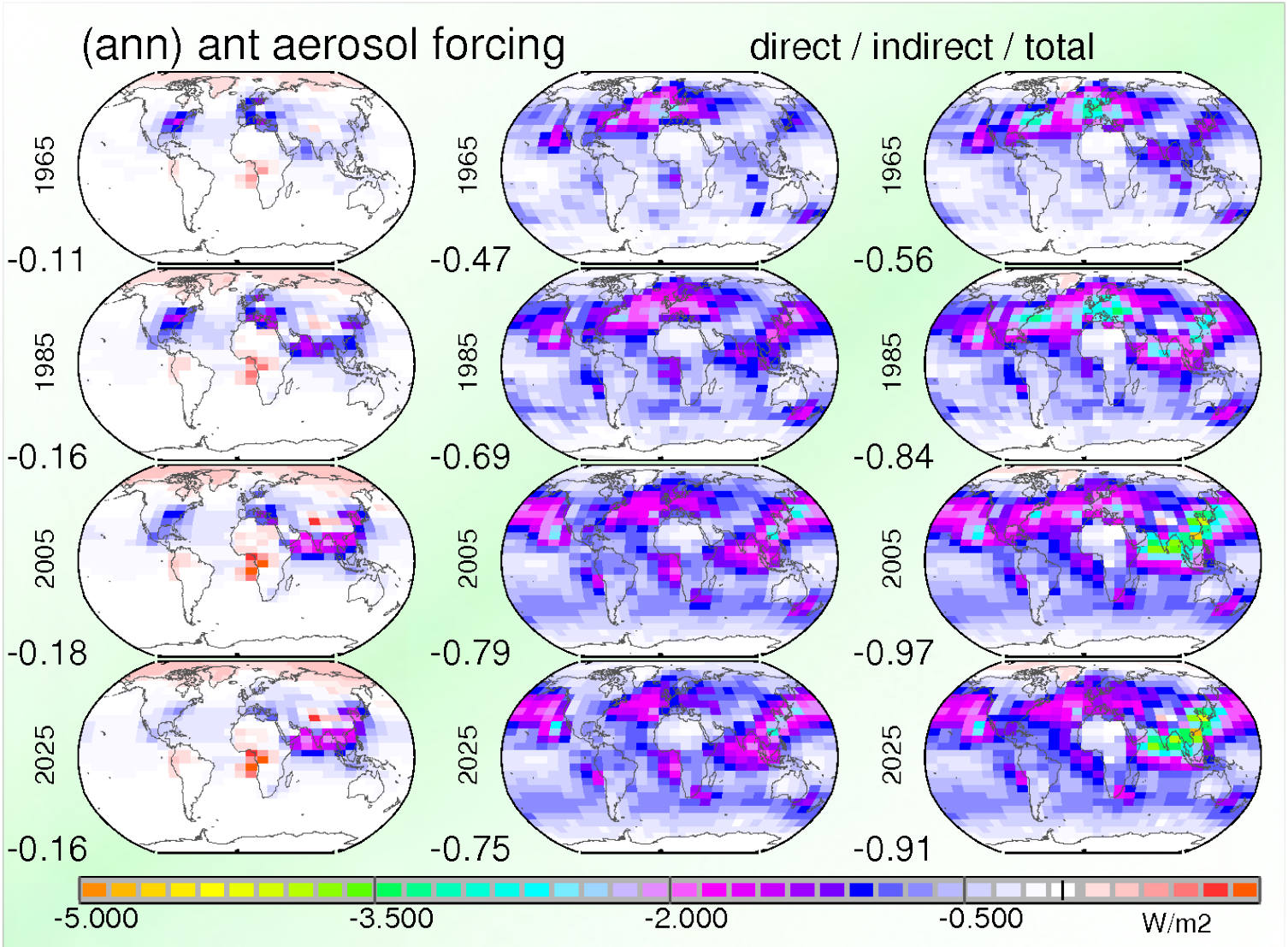


2005 indirect anthrop forcing

-0.8 W/m2

aerosol forcing – 1965 to 2025

direct **indirect** **total**



aerosol forcing highlights

- aero forcing has not changed much since 1985
  - regional shift though: US/EU → SE-Asia
- indirect (cloud effects) dominate TOA response

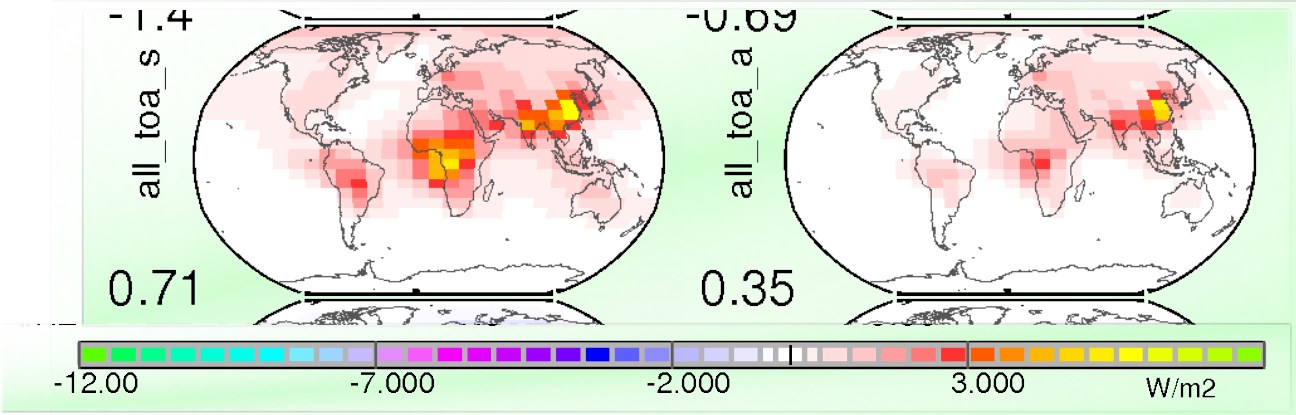
  -0.8 W/m2 (indirect) -0.2 W/m2 (direct)
- aerosol absorption dominate the atm heating

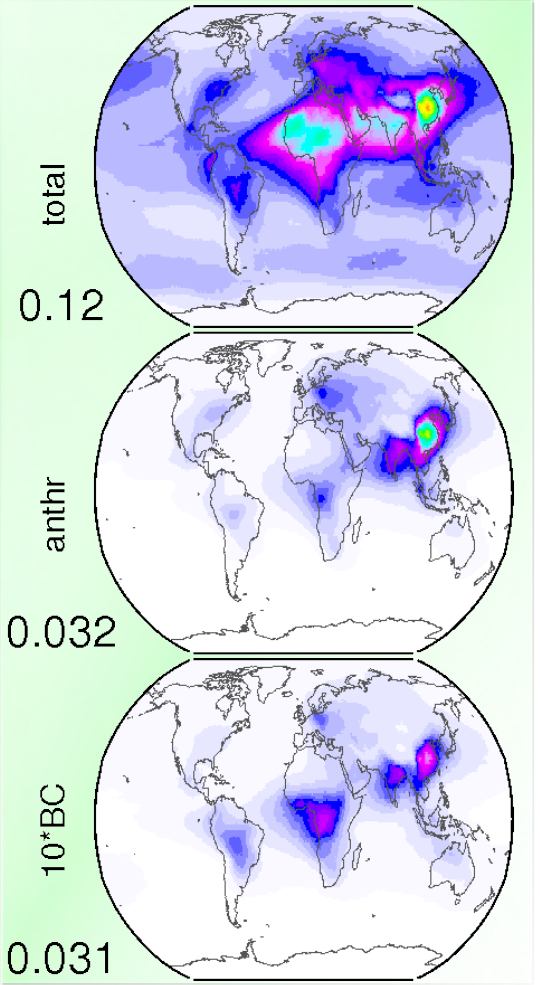
  -1.1 W/m2 (direct)
- AOD dominate the response at the surface

  -1.3 W/m2 (direct)
- strong spatial (and also seasonal) variability

BC forcing – 2005

total BC **anthrop BC** **AOD-fields**





- what is the natural background ?
- anthrop BC effects
  - TOA forcing +0.35 W/m2
  - atm forcing +0.95 W/m2

summary

- all aerosol properties are highly variable
  - different sources, short lifetime, transport
- although global averages are given …
  - maps display diversity (e.g. source regions)
- regional impacts are often an order of magnitude larger than global averages
  - the indirect global aerosol forcing is -.2 W/m2
    regional responses range from -6 to +6 W/m2

finally Bill

- didn't we all hate to get interrupted during presentations by Bill …
  - sometimes valid, sometimes for his pleasure
- but there is also a gentler & constructive side
  - … once you get to know him
- in that way his resembles his 'German twin'
  - unfortunately also in terms of recent health issues
- so *…with wishes from Ehrhard*
  - get well ! … and
  - keep challenging us !

Max-Planck Aerosol Climatology

ftp ftp-projects.zmaw.de/aerocom/climatology/MACv2_2017

- 1x1 deg global, monthly, aerosol opt. properties
- capturing today's average properties for
  - column amount ('attenuation') AOD
  - column absorption ('composition') AAOD
  - particle 'size' information FMF, Angstrom

– how? …. combine!

- quality statistics from sun-photometer data
- completeness from bottom-up modeling

relying on OBSERVATIONS of AERONET and MAN plus background from modeling

(no direct use of satellite data)

AerChemMIP AeroSAT ccmi AeroCom

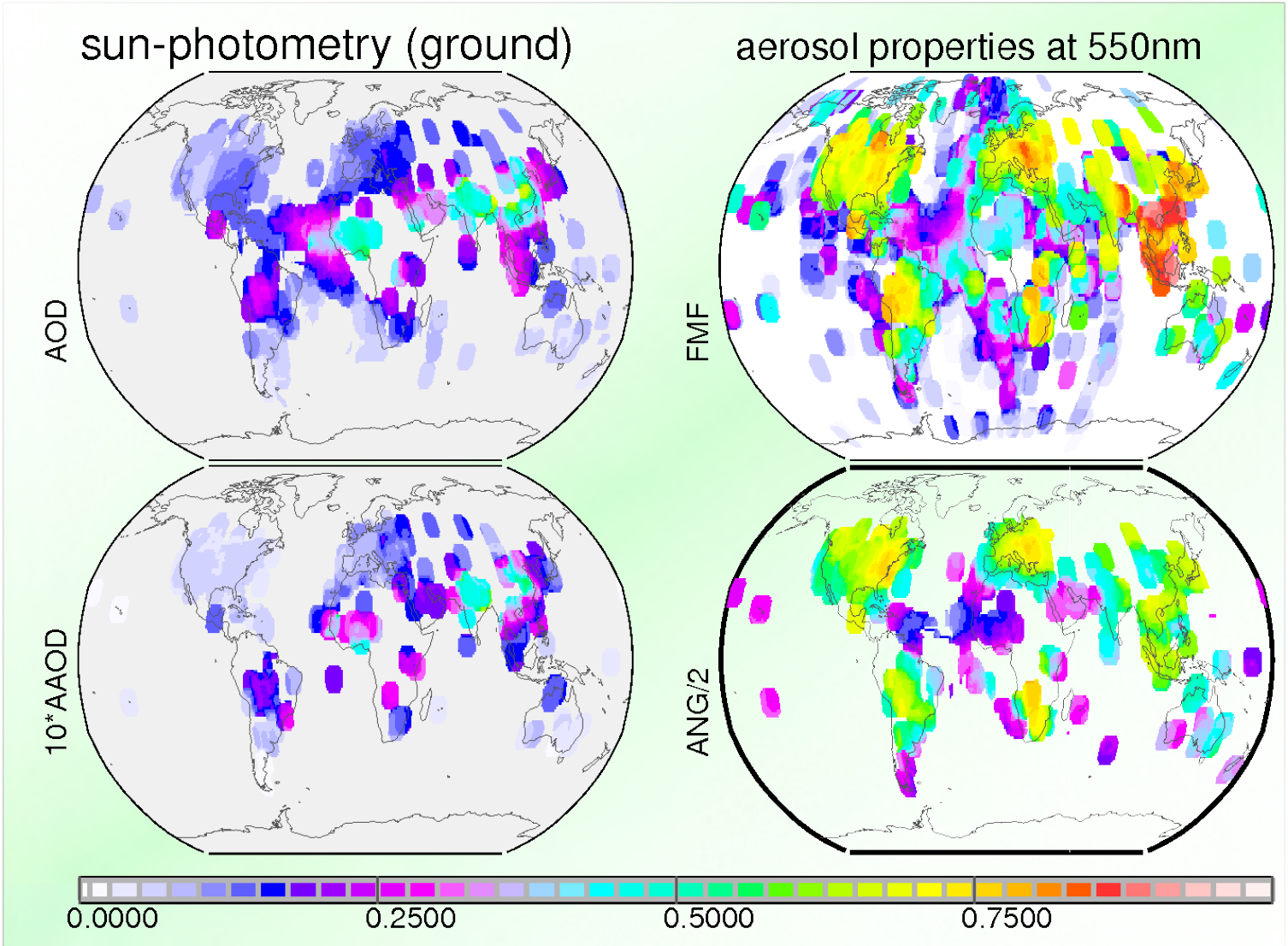
why MAC ?

… climate studies require aerosol rad. properties

- simulations from global modeling
  - accuracy suffers from input and complexity
  - time-consuming
- prescription by a climatology (e.g. MAC)
  - direct link to observations
  - fast (and simple to implement)

while the climatology can be a nice option in many applications … the reliance on context from global modeling underlines to importance on advancements in detailed aerosol modeling

use observations if you can



AOD

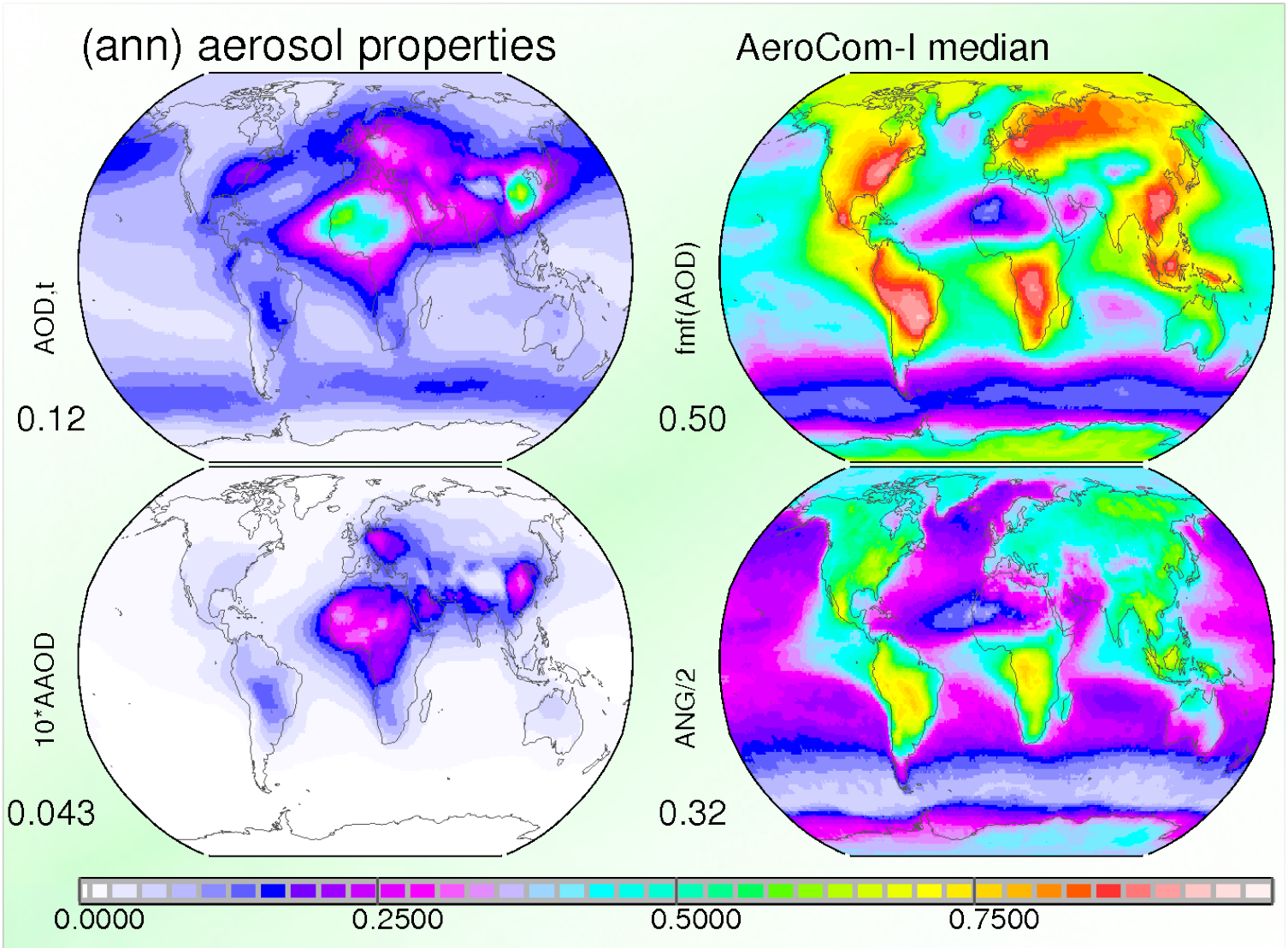
AAOD
(10 times)

FMF

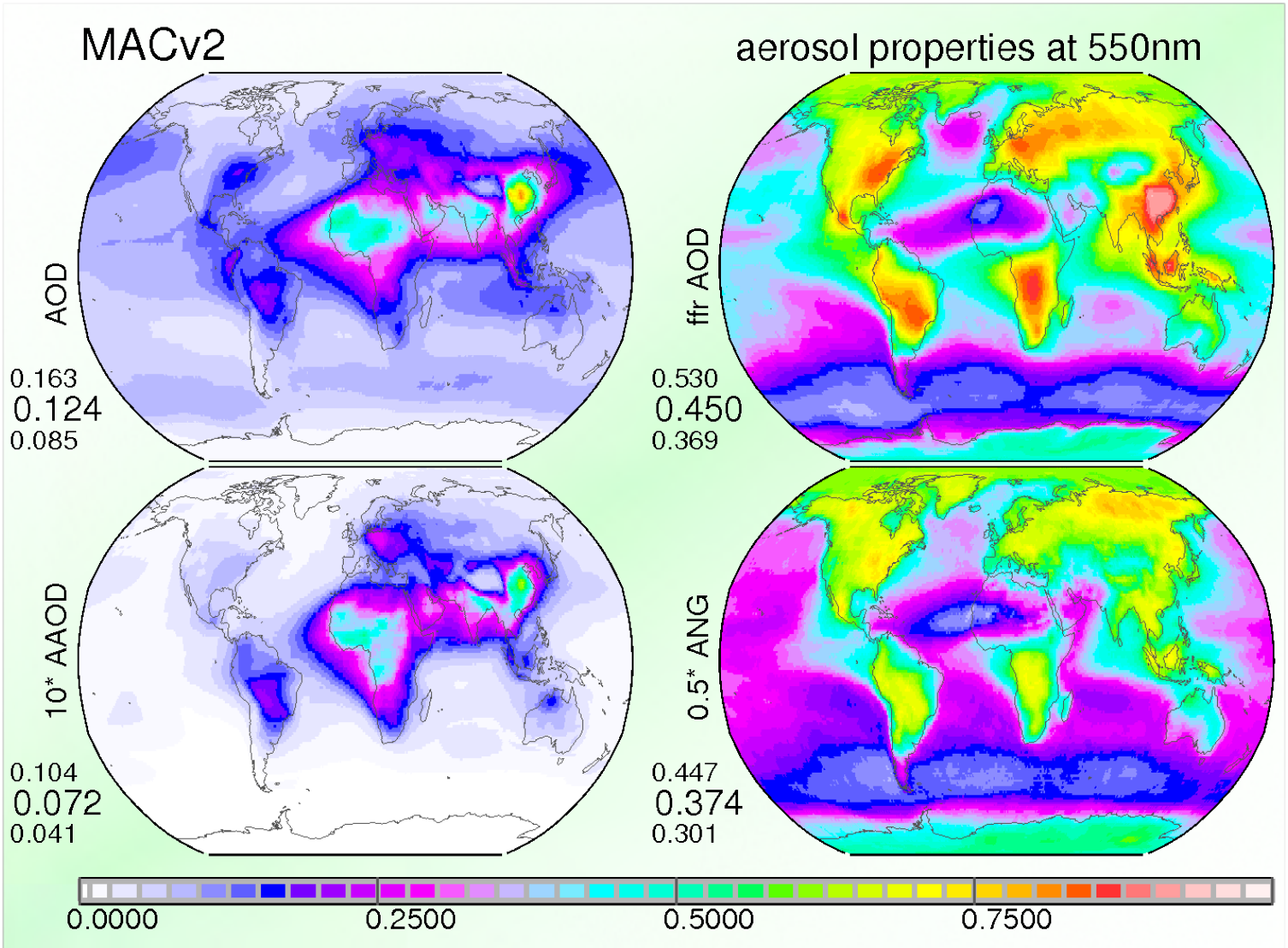
ANG
(div by 2)

annual
means

complete modeling



extended with model context → MACv2



AOD

AAOD
(10 times)

FMF

ANG
(div by 2)

annual means

particularly useful with extra help

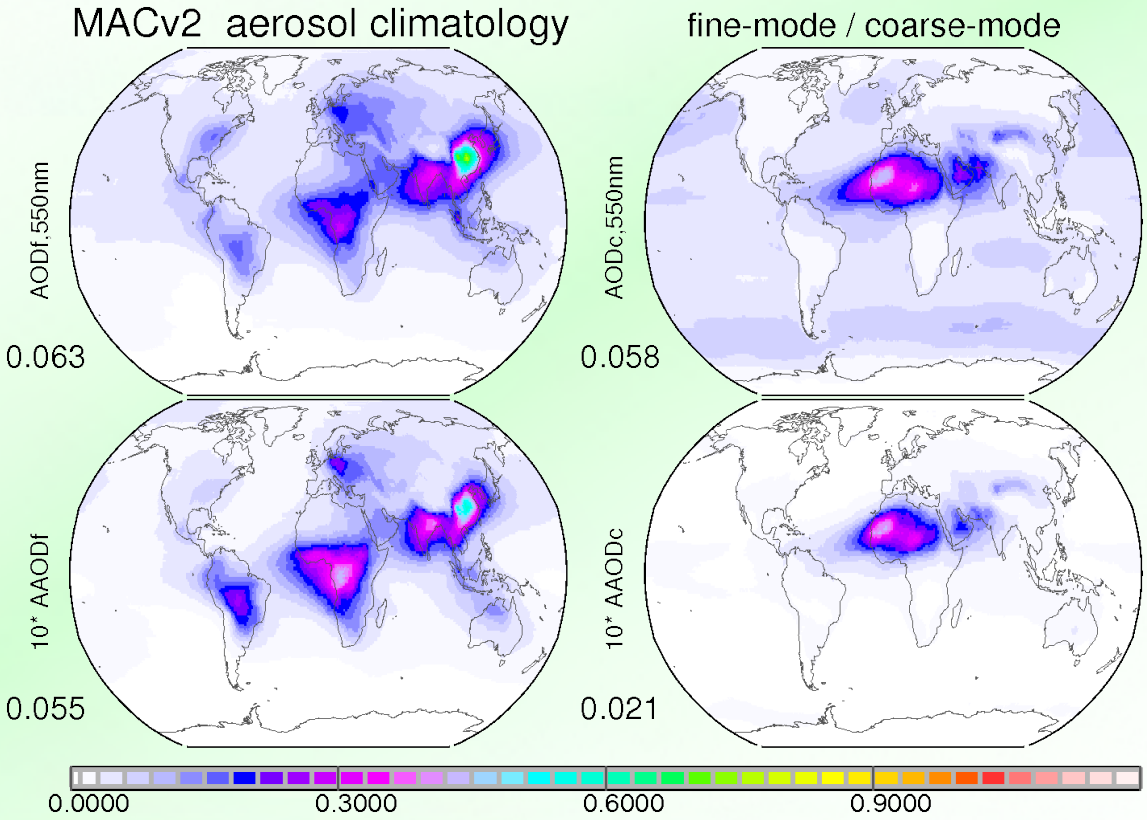
- to make it useful for climate applications
  - anthropogenic fraction
    - fine-mode only (no anthrop dust)
  - temporal variability (seasonality)
  - temporal variability (inter-annual)
    - only anthrop AOD change (const coarse-m.)
  - spectral variability
  - vertical distribution
  - microphysics (fine-mode size → CCN conc.)
    - changes to low cloud properties

ver.2 vs ver.1 (what changed?)

- merge absolute quantities, now in two steps
  - not relative properties (SSA, FMF, …)
- use MAN data over oceans
  - reduced dep. on modeling
- use a different (higher) PI fine-mode state
  - anthropogenic AOD dropped by 30%
- outcome
  - AOD remains similar, but anthrop AOD smaller
  - AAOD is much stronger
    - less direct forcing (-0.5W/m2 to -0.2Wm2)

recent ver.2 update (what changed?)

- **better absorption attribution to size-modes**
  - **allows now to quantify aerosol components**



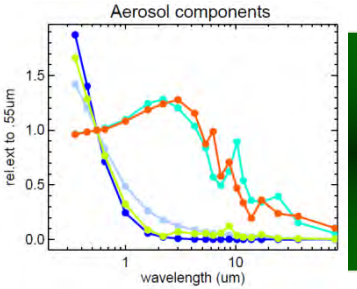
fine AOD 50%

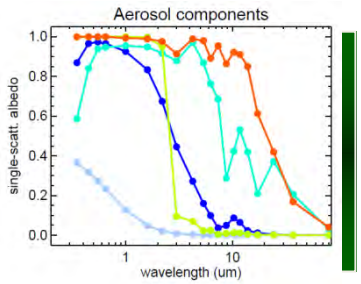
coarse AOD 50%

fine AAOD (10 times) 70%

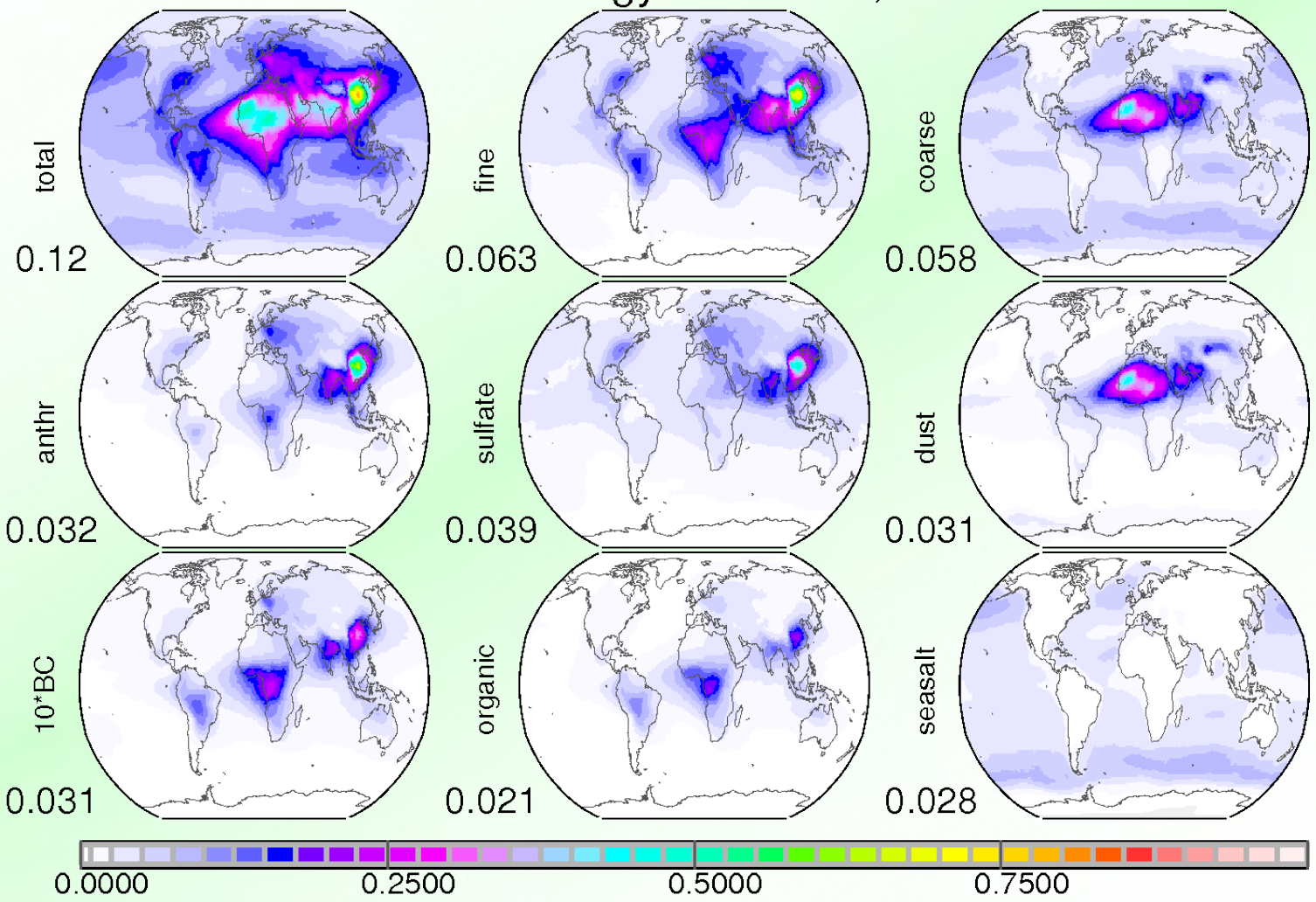
coarse AAOD (10 times) 30%

AOD by components

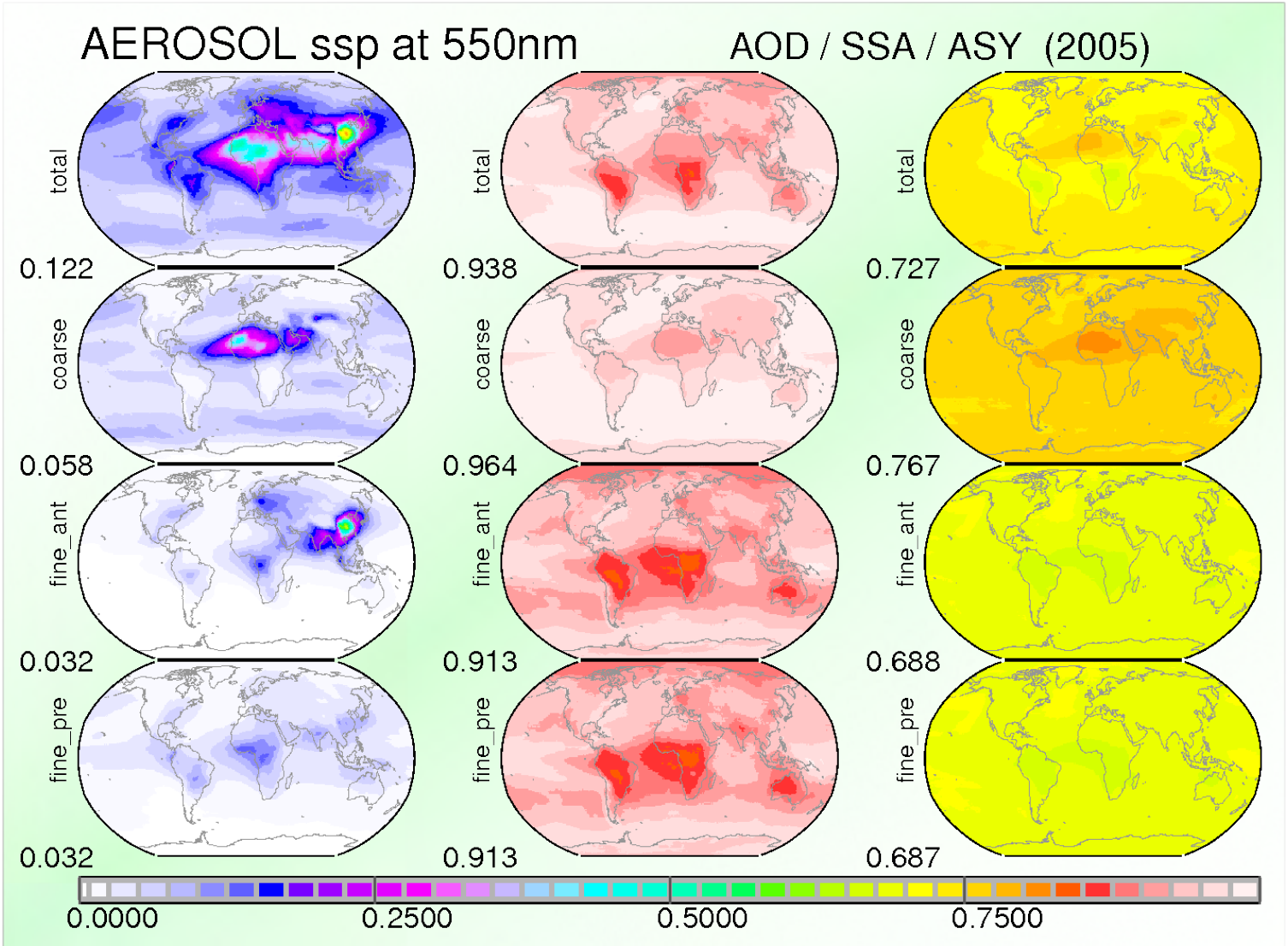




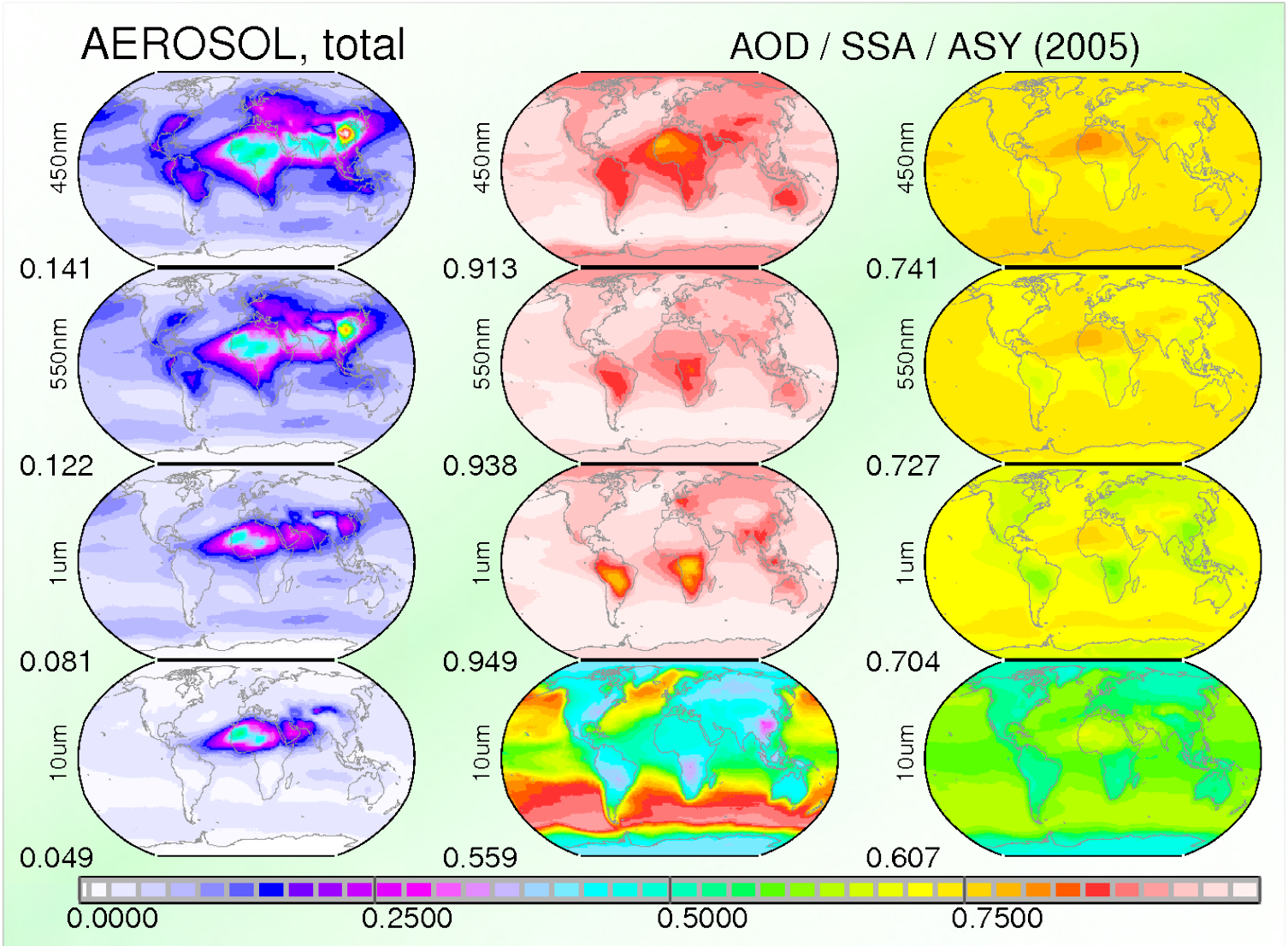
- **BC** black carb
- **OC** org. carb
- **SU** sulfate
- **DU** dust
- **SS** seasalt



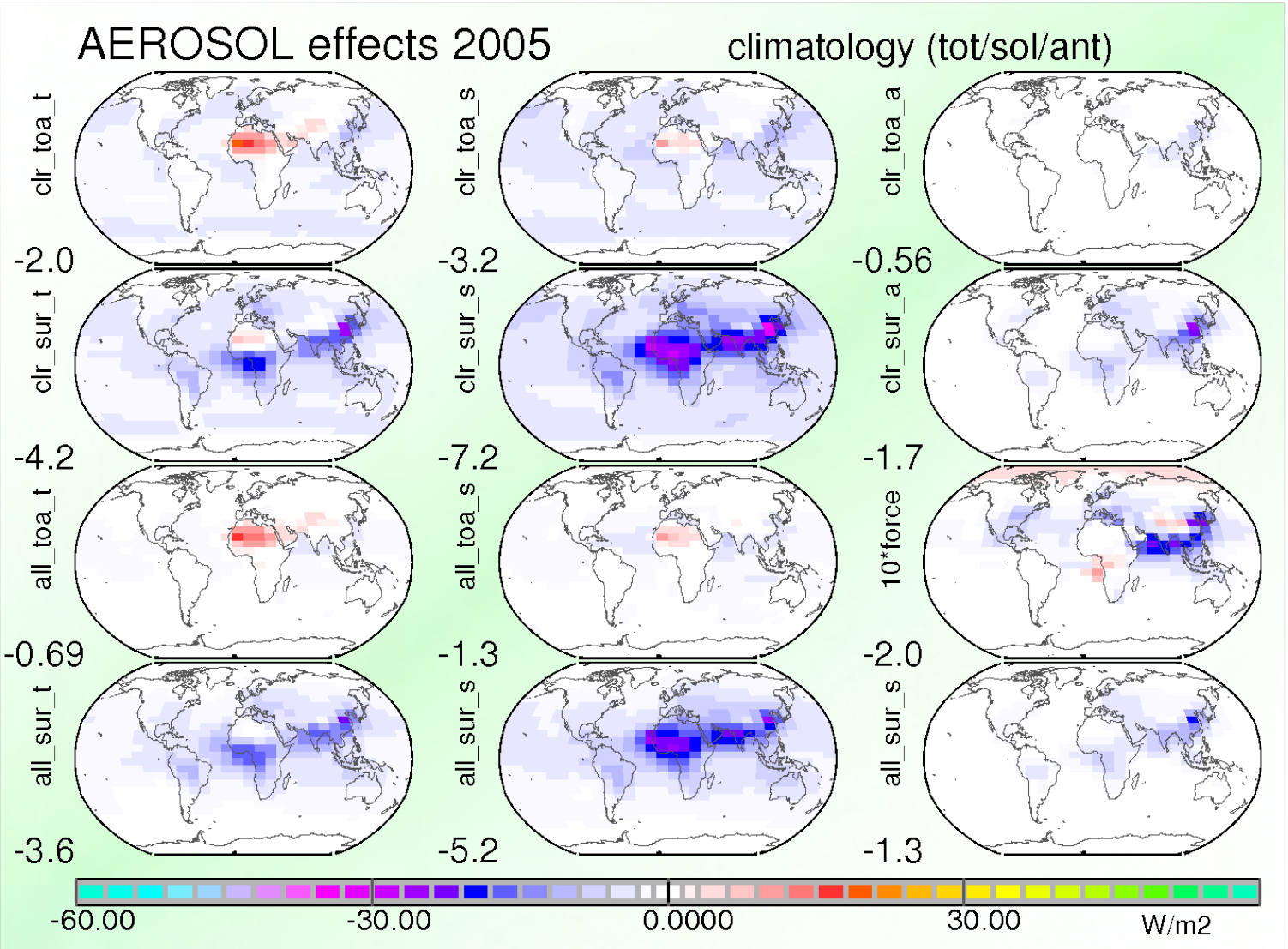
AOD SSA ASY rad. transfer needs



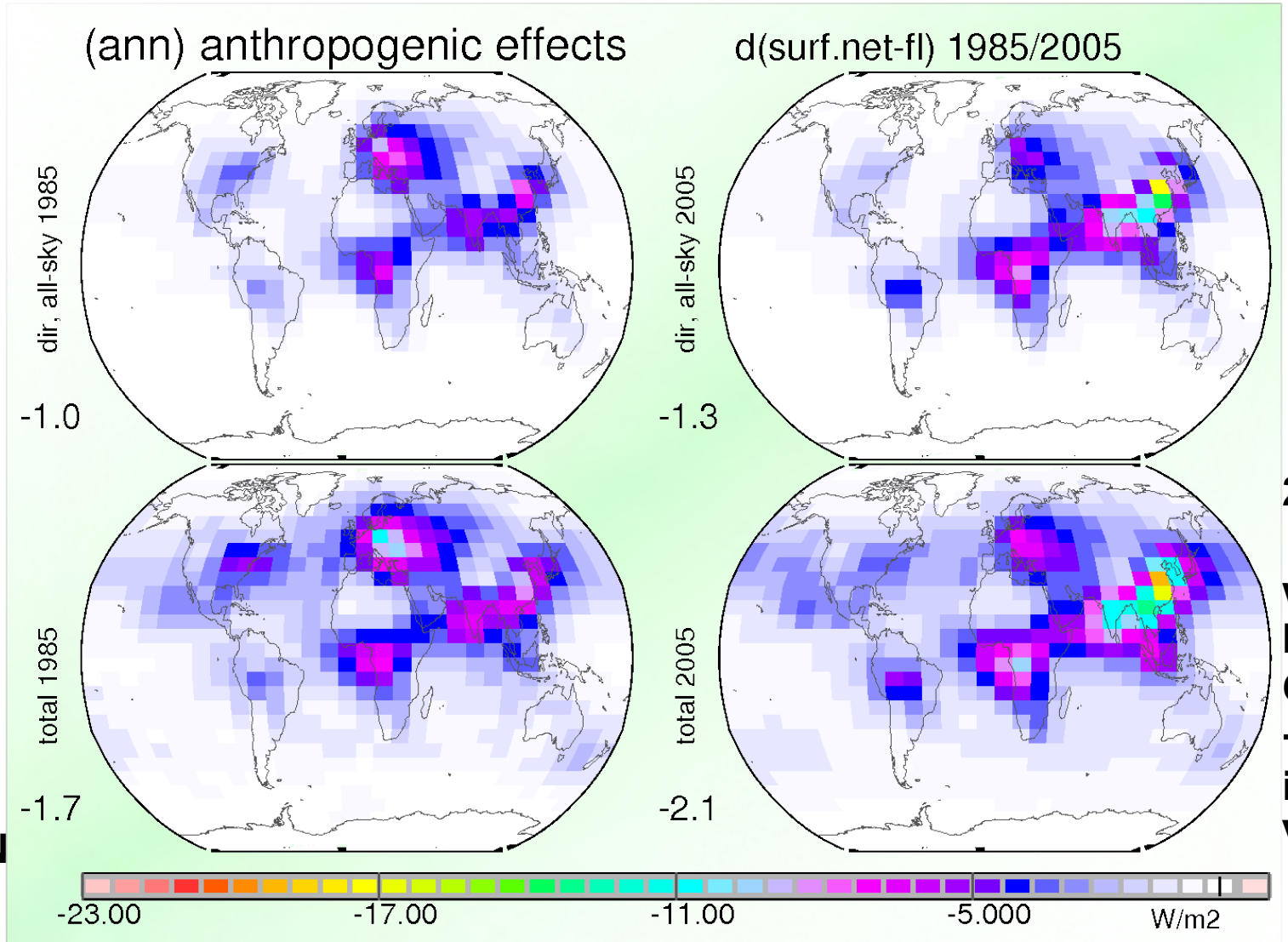
AOD SSA ASY rad. transfer needs



dir rad. impacts



changing impact on surf net fluxes



1985 clr-sky

2005 clr-sky

1985

with ISCCP Clouds + indirect Via CCN

2005

with ISCCP Clouds + indirect Via CCN

final slide

- update for MACv2 is available

ftp ftp-projects.zmaw.de/aerocom/climatology/MACv2_2017

  - next monthly pdf in place of single value
  - considering changes in fine-absorption
  - for specific spectral data needs: contact me

- forcing (and rad.effects)
  - indirect (via clouds) eff.s most import at TOA
  - direct effects most imp. in atm and at surface
  - over the last decades the aerosol induced reductions to on surface net-fluxes increased

fit properties to pre-defined components

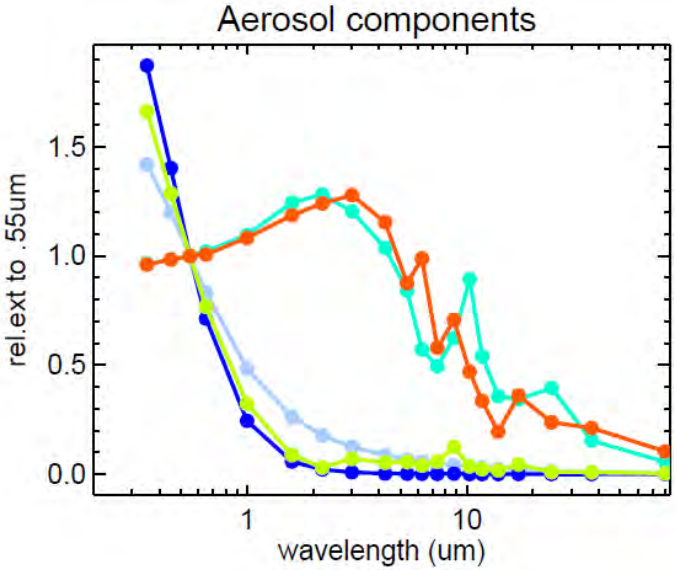
BC
black carb

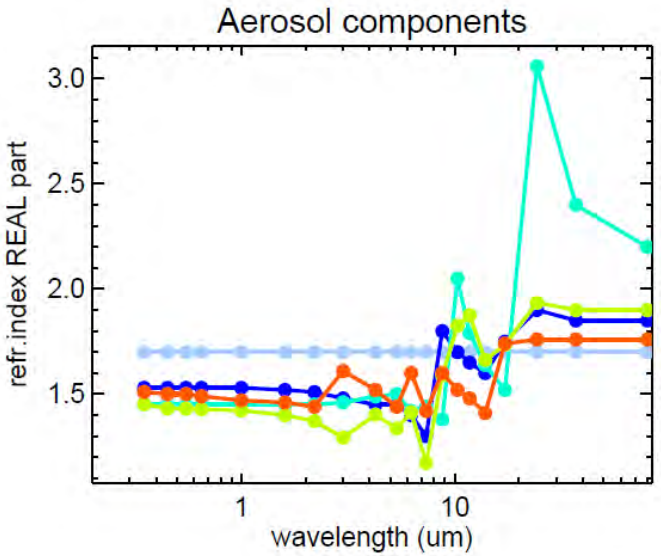
OC
org. carb

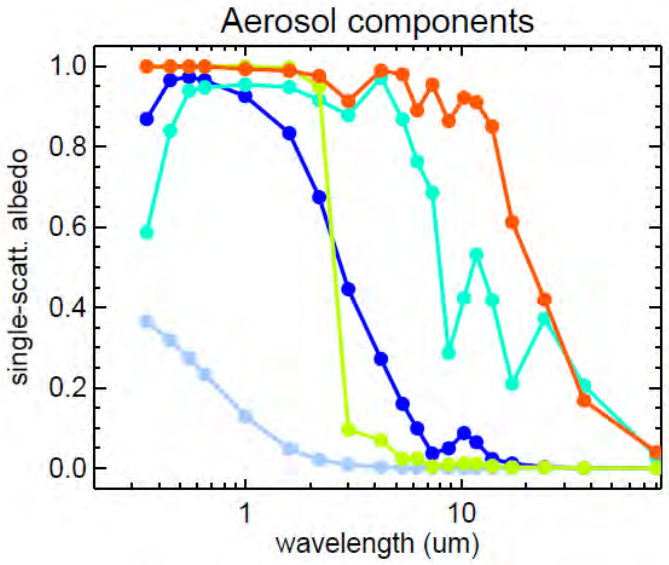
SU
sulfate

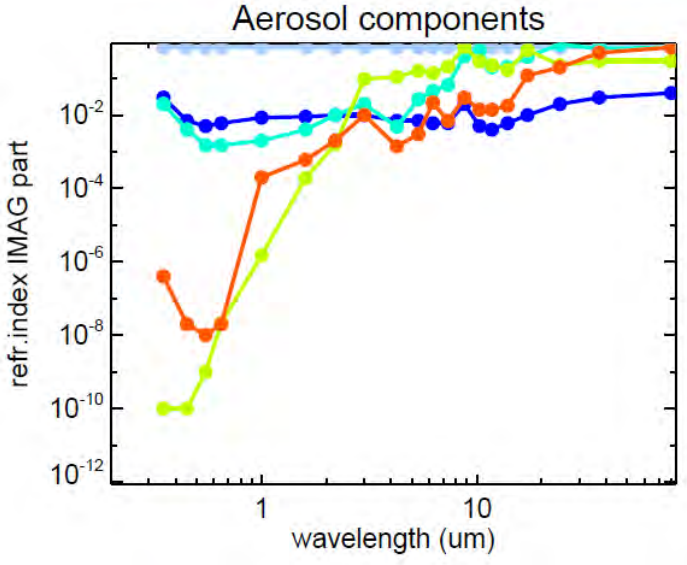
DU
dust

SS
seasalt

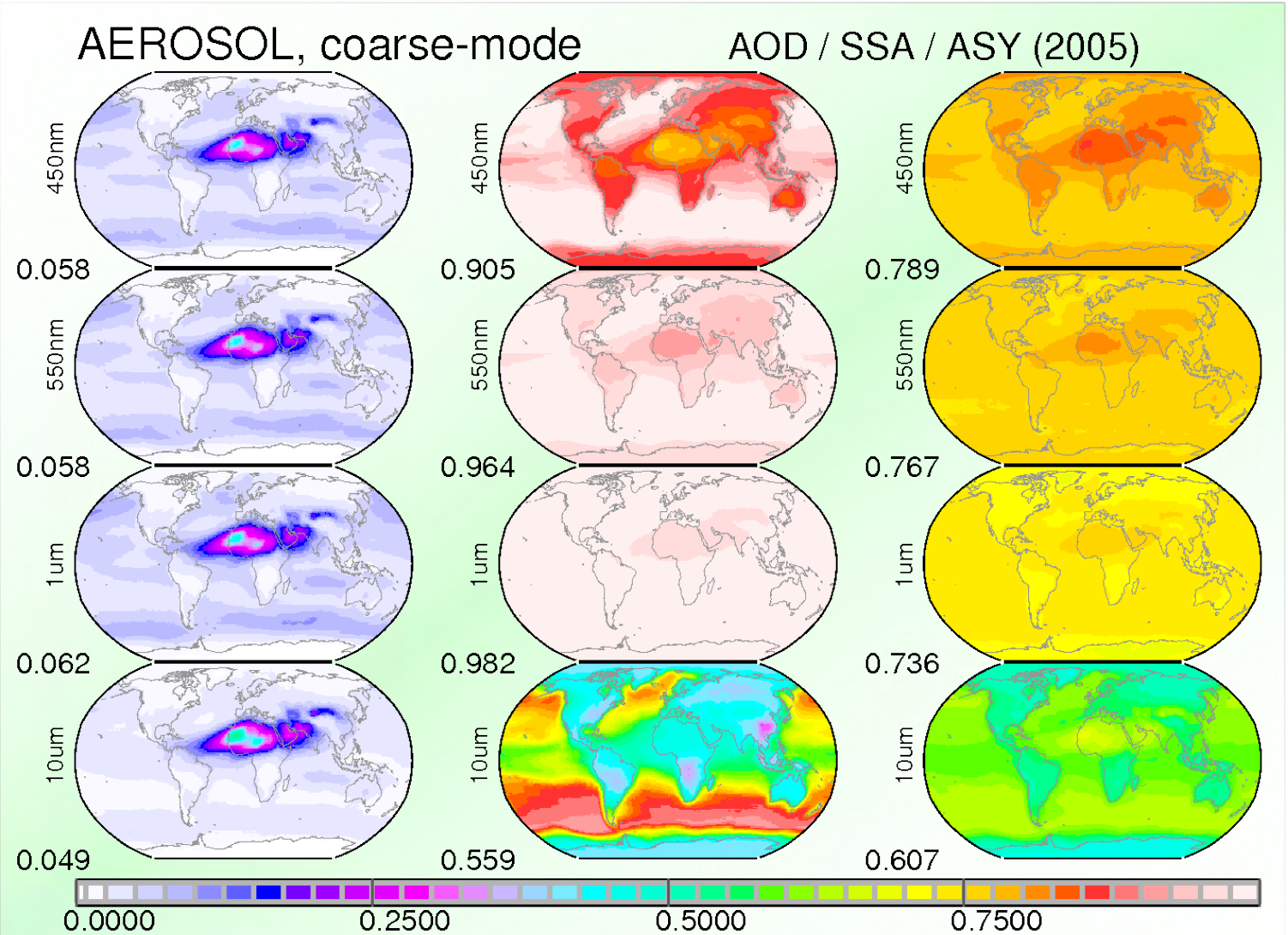




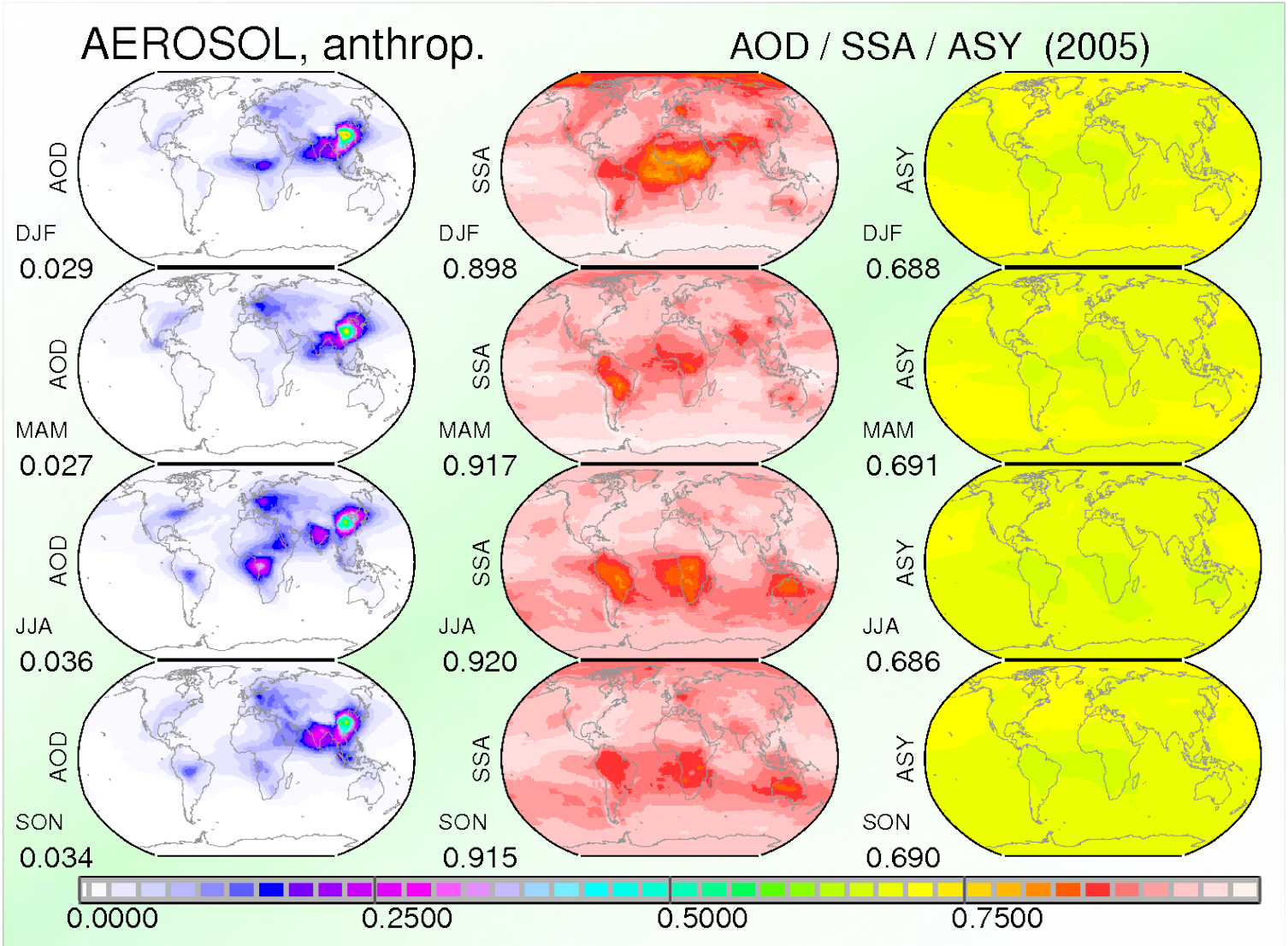




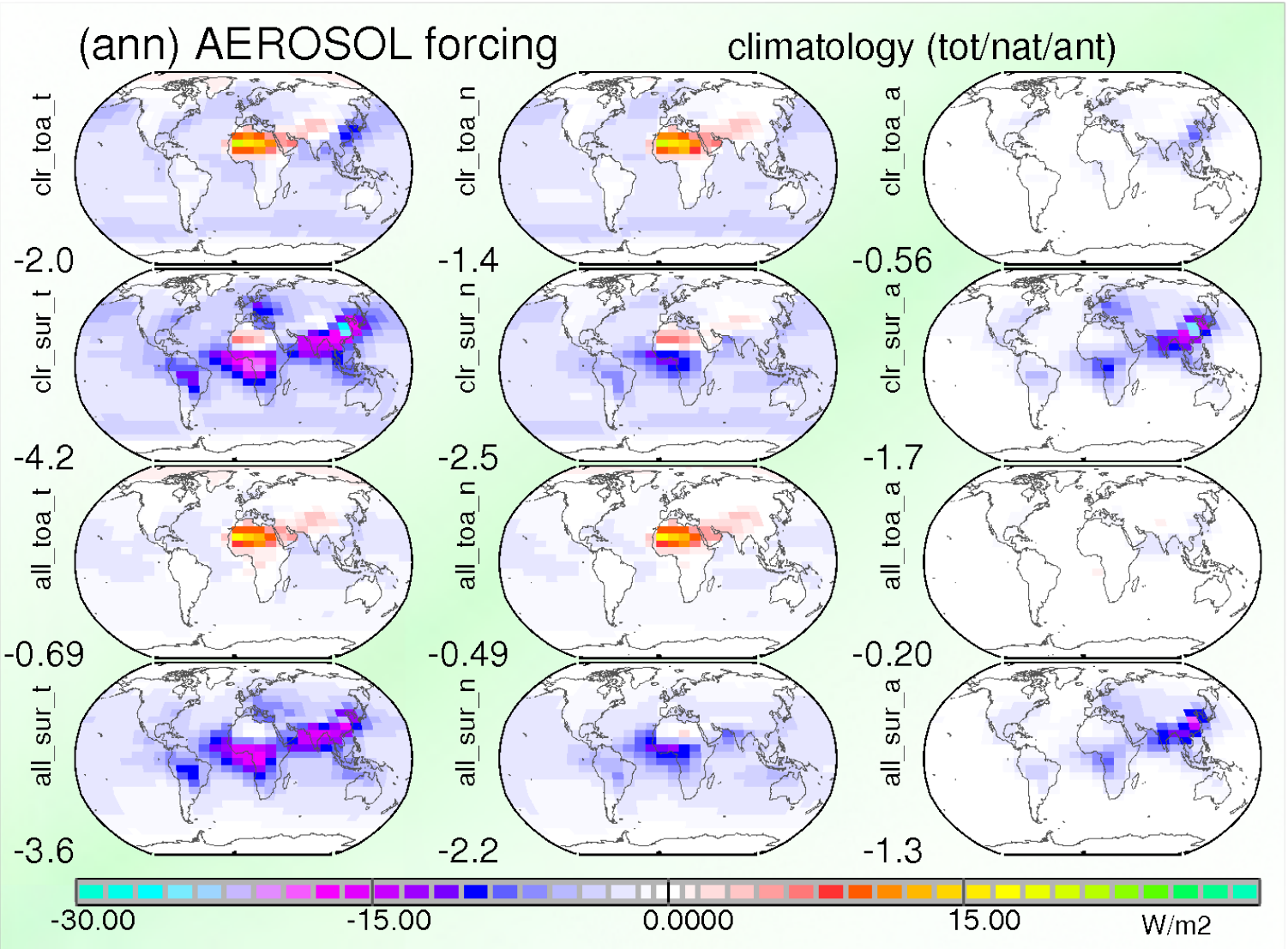
coarse mode spectral



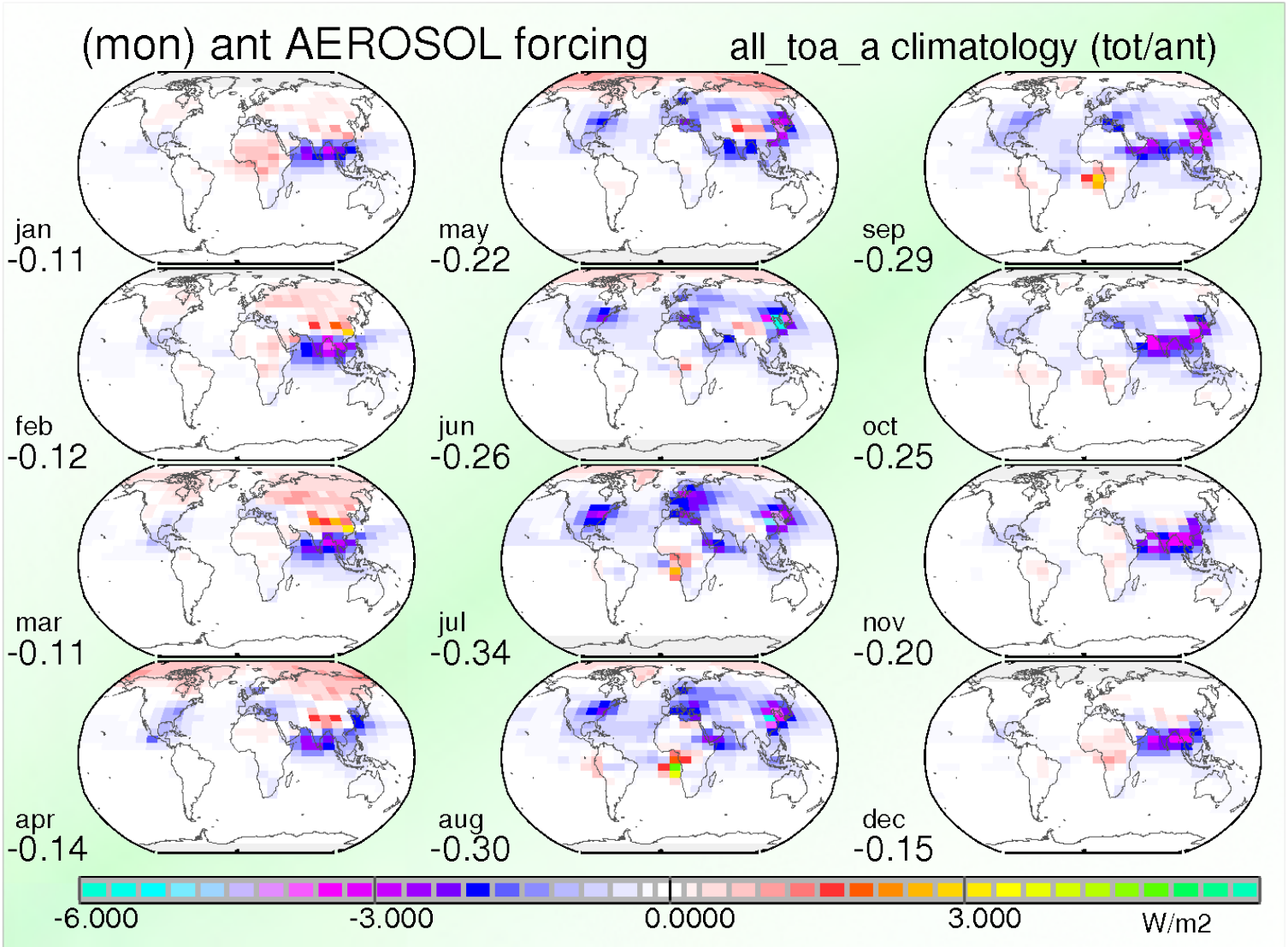
anthr. / fine mode spectral



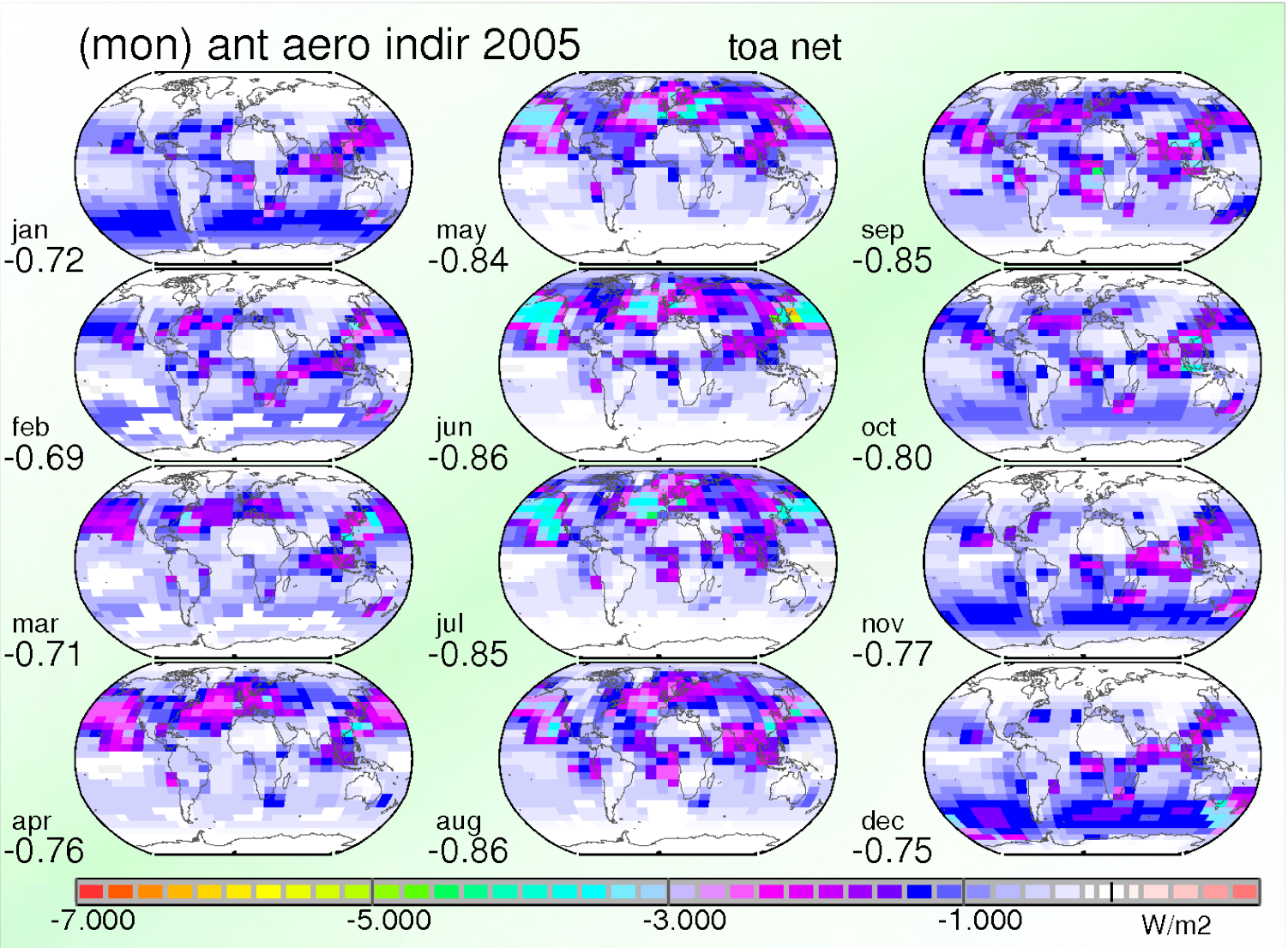
direct rad.effects overview 2005



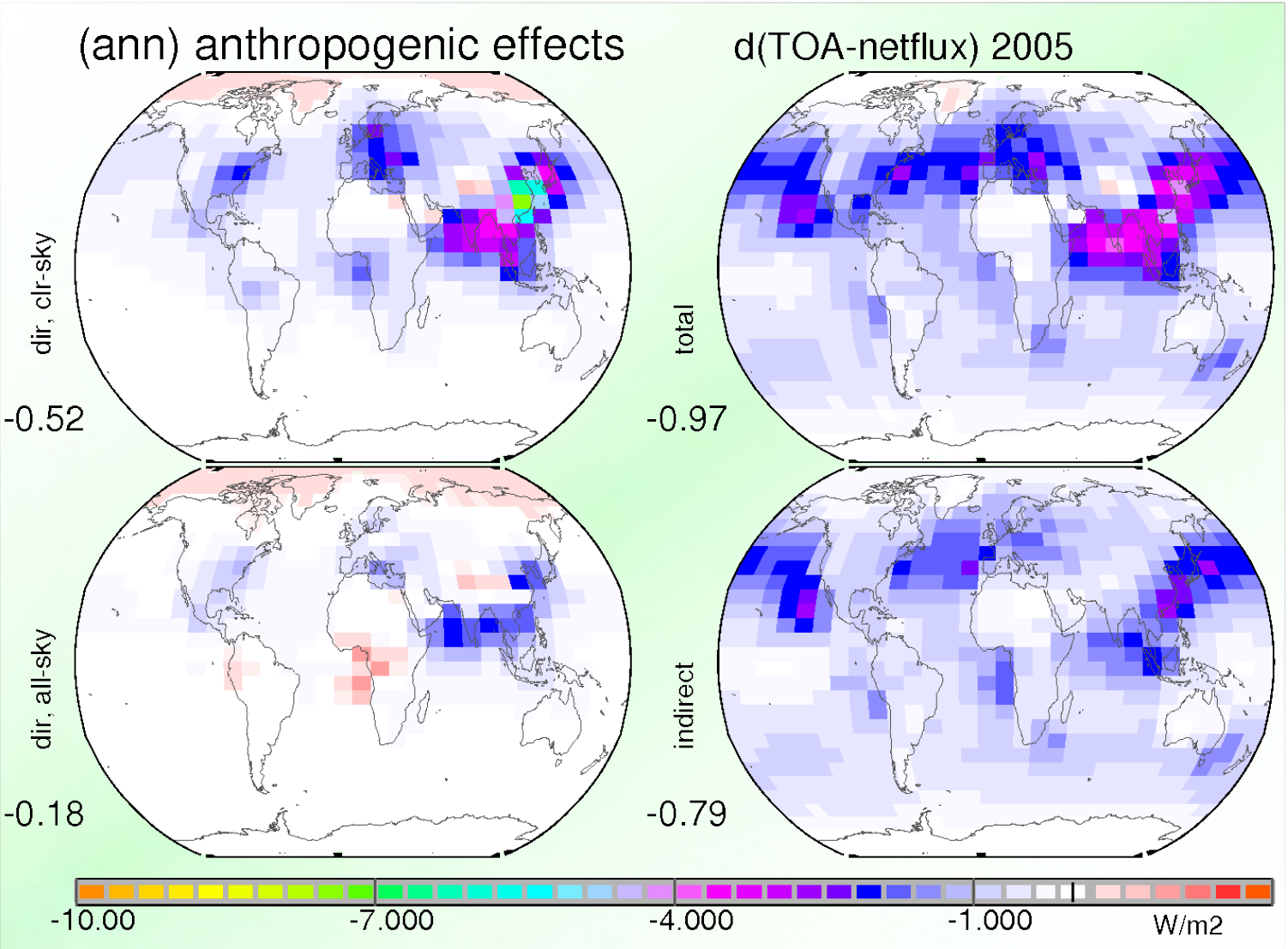
direct anthrop TOA effect



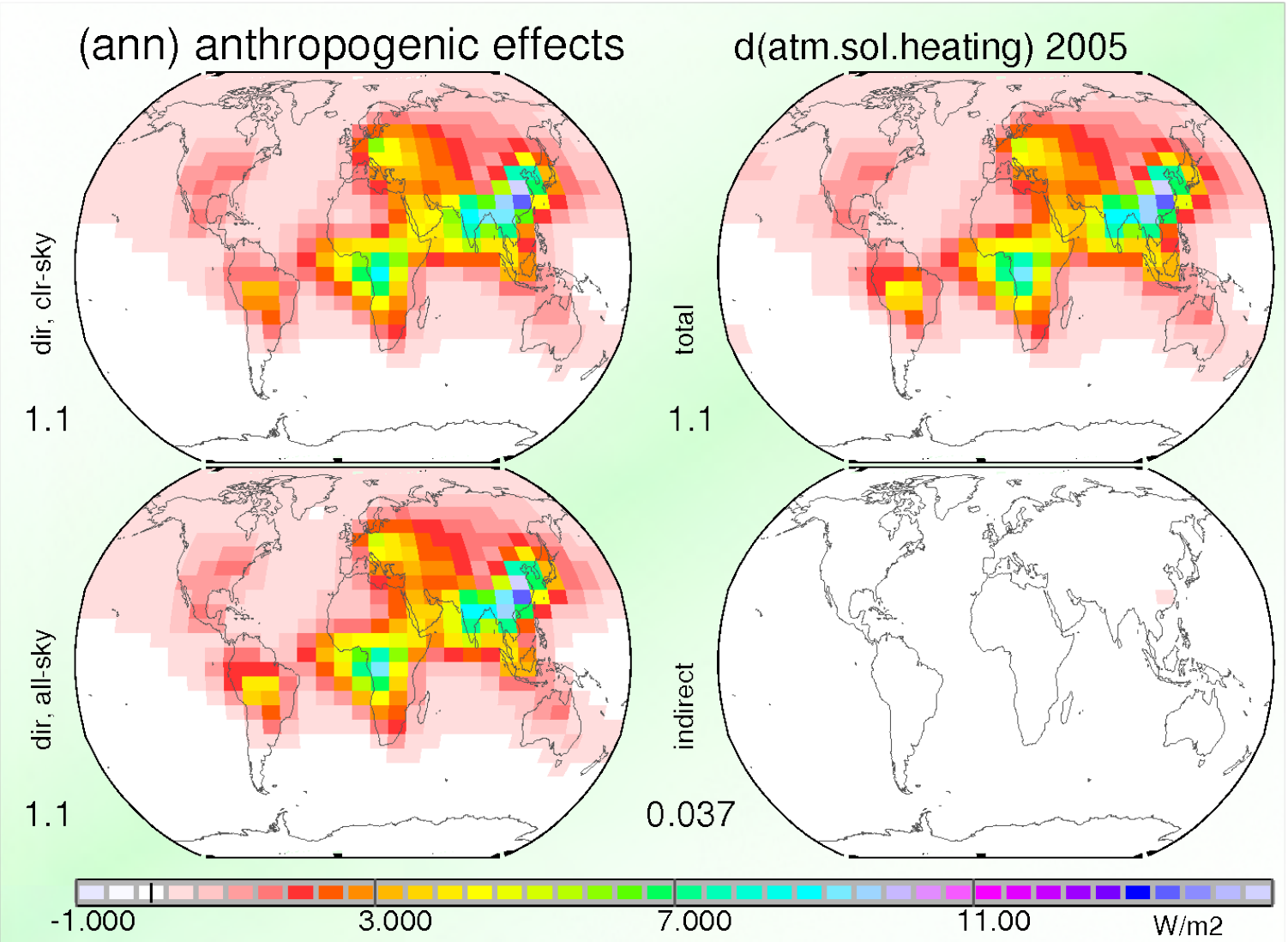
indirect anthrop TOA effect



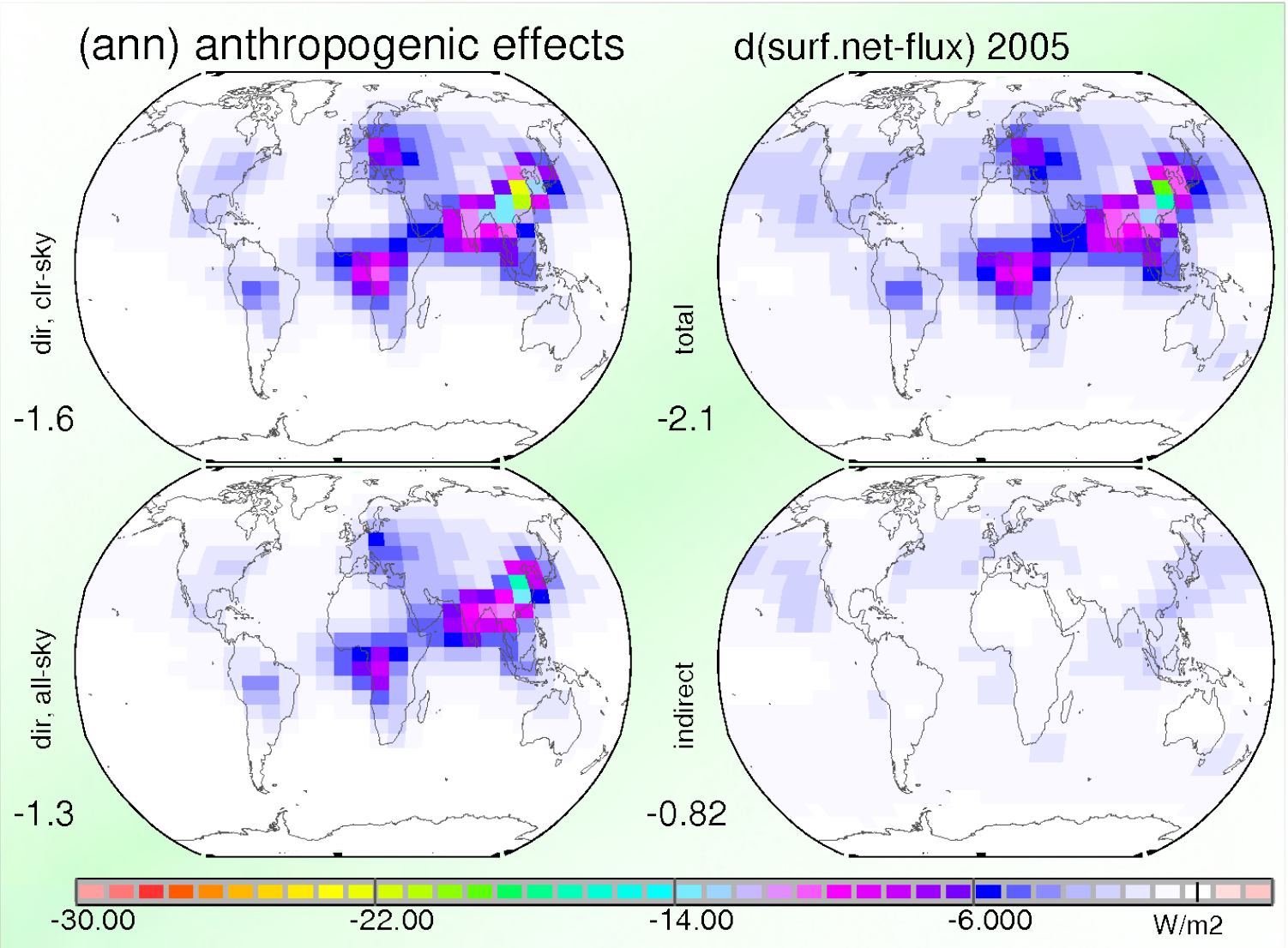
TOA components 2005



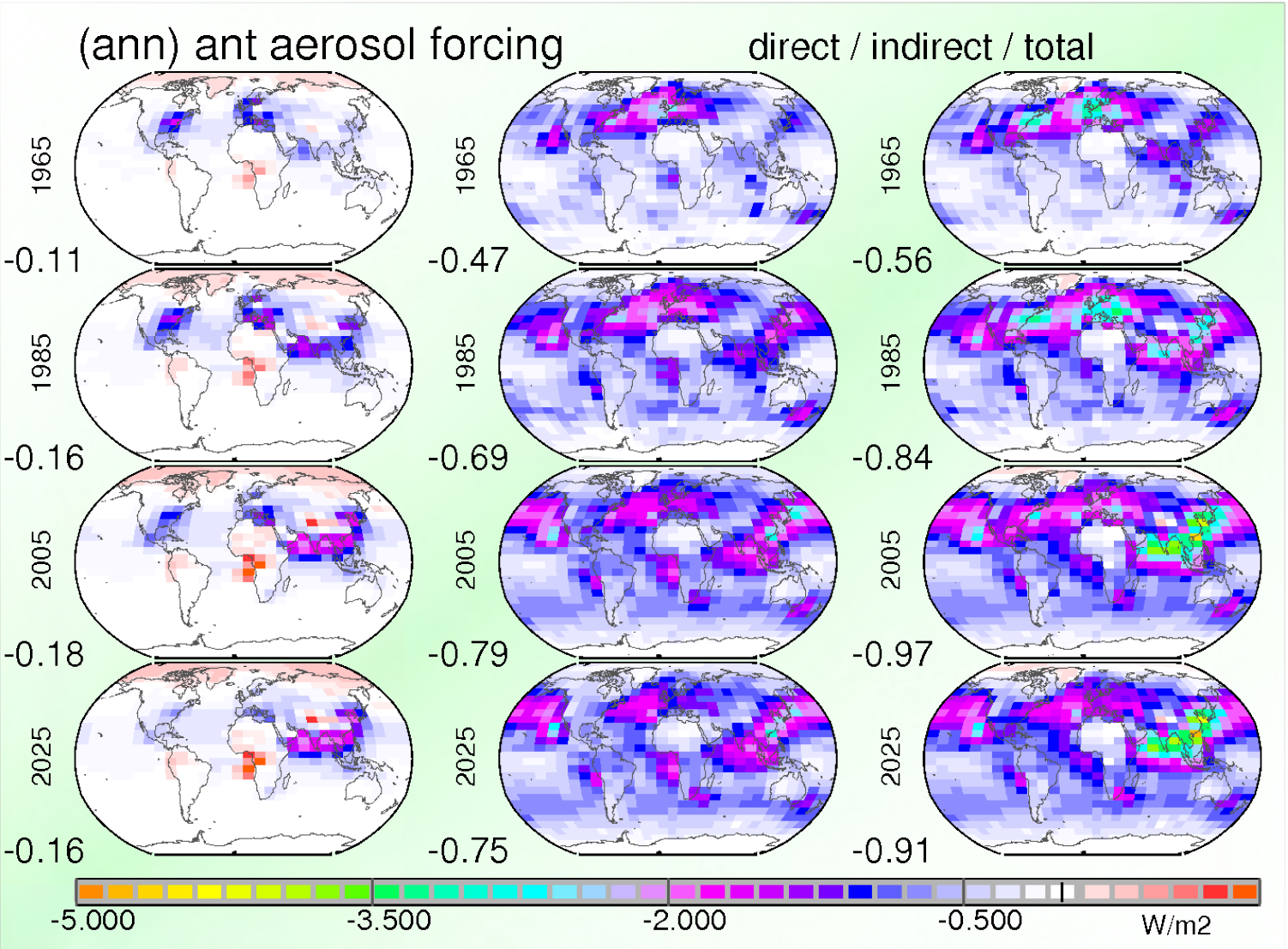
atm components 2005



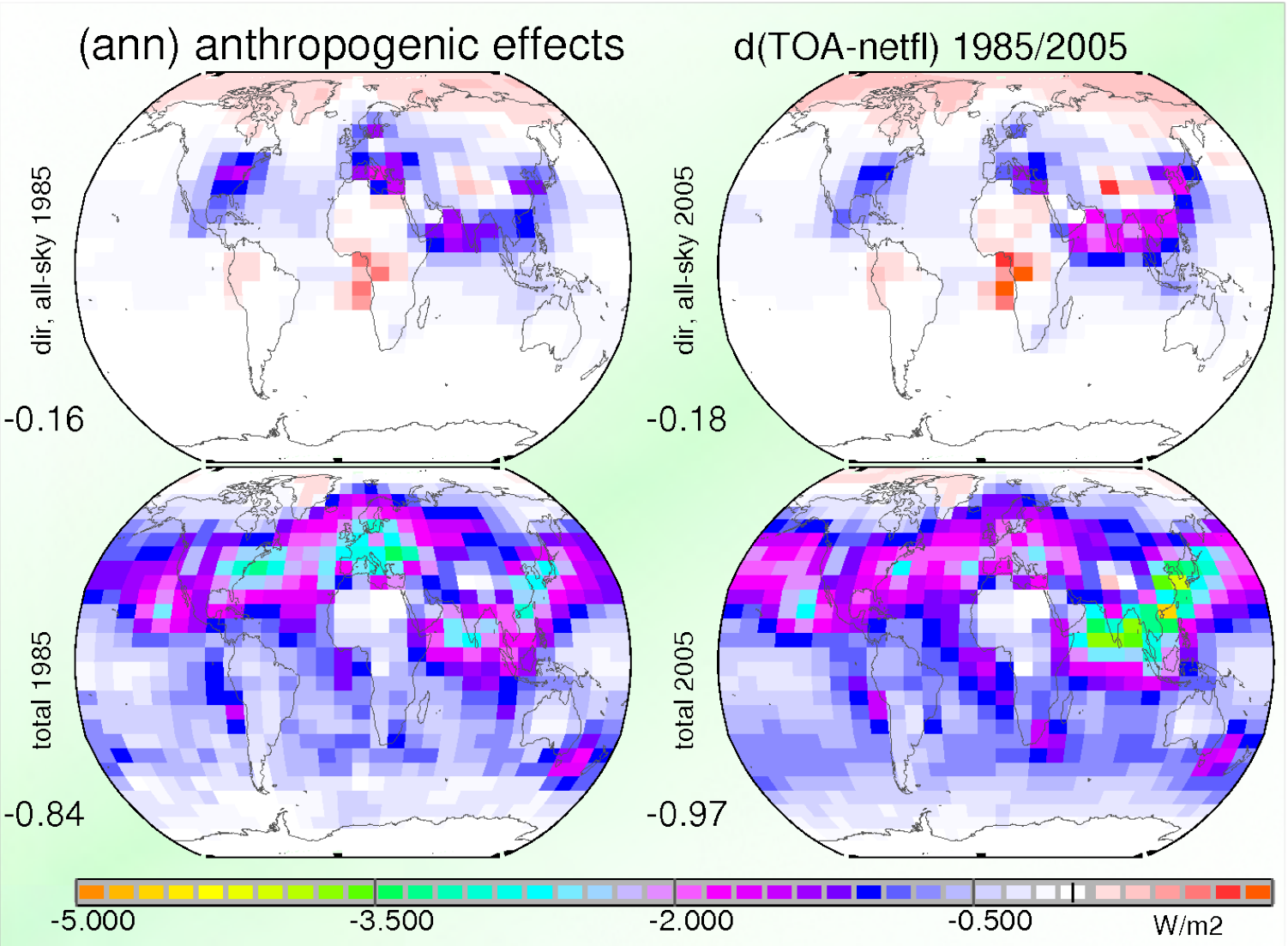
surface components 2005



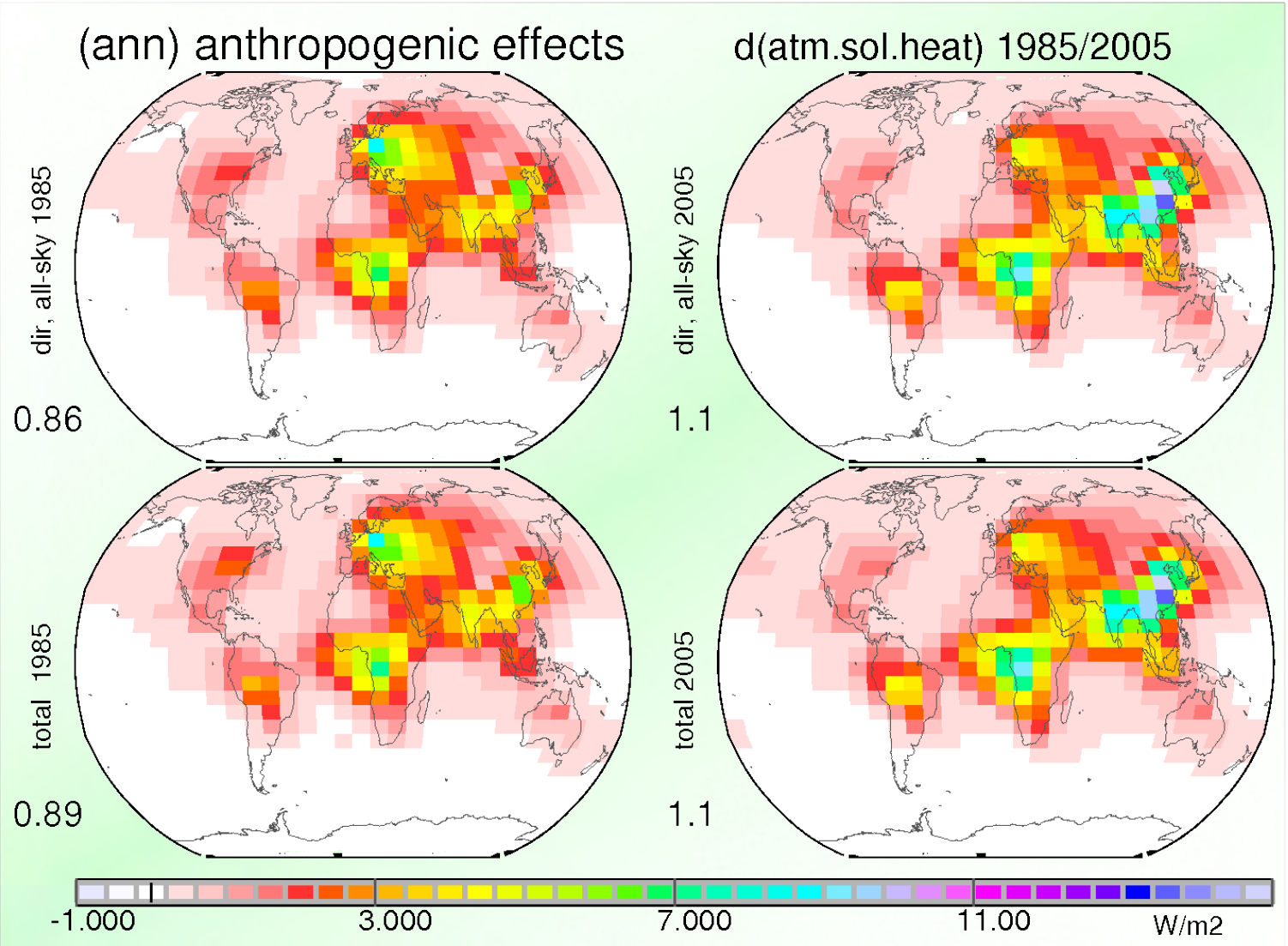
forcing over time



TOA - 1985 vs 2005



atm - 1985-2005



rad transfer simulations

'all components' minus 'all without BC'