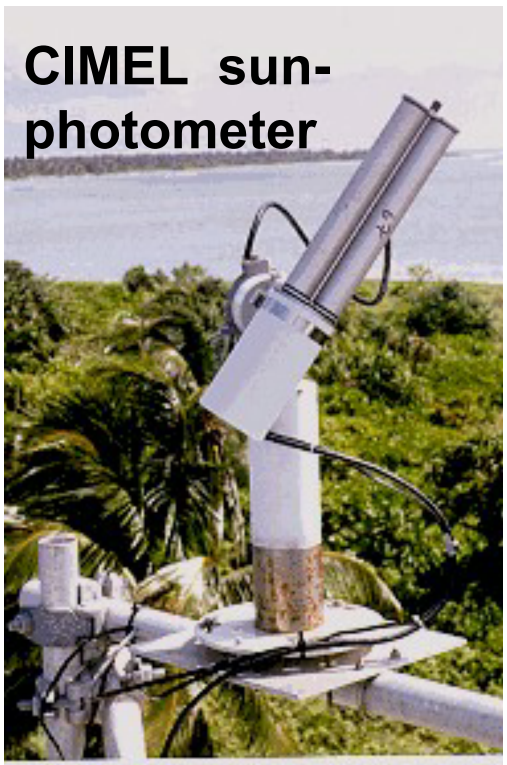
aerosol climatology

and applications



S. Kinne
and colleagues

MPI-Meteorology

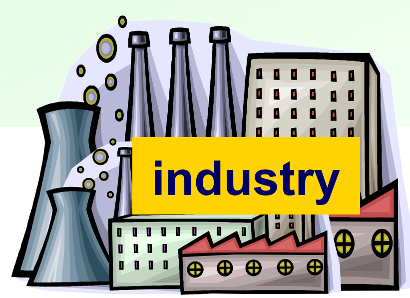
with support by
AeroCom and AERONET

aerosol - a complex atmos. ingredient

- **aerosol** *('small atmos.particles')*
  - many sources
  - short lifetime
  - diff. magnitudes in size
  - changing over time
    - aerosol ←→ clouds
    - aerosol ←→ chemistry
    - aerosol ←→ biosphere
    - aerosol ←→ aerosol

highly variable in space and time !

rapid atmospheric 'cycling'



simplify !

- aerosol modules can be (very) expensive
  - stratification by type and size
  - mixing states, phase transitions, chemistry
  - environmental processing (e.g. clouds)
    - … still important processes may be missed
- 'climate applications' demand simplifications
  - what are the optical properties ?
    - … to quantify (direct) radiative impacts
  - what are is CCN / IN concentrations ?
    - … as a link to (indirect) radiative impacts

past simplifications

- optical properties
  - Tanre CLIMATOLOGY (1984 !)
    - dust - 'bubble' over Africa RF(1.55, 0.005)
      → 20 W/m2 too much solar absorption
  - Koepke GADS / OPAC (1997)
    - 10 aerosol types → mixtures allowed
    - size (&opt. prop) function of relative humidity
    - only for jan and july, 5x5 resolution
- CCN estimates
  - Nakajima AI ~ CCN (2001)
    - AI = AOD * Angstrom

revisit climatologies

better and more observations

- **10 + years sun-/sky-photometer networks**
  - **statistics from ca 500 sites**
- **10 + years dedicated satellite sensors**
  - **MODIS, MISR, POLDER, OMI, ATSR, CALIPSO**

advancements in modeling

- **detailed aerosol component in global modeling**
  - **AeroCom, …**
- **kappa method (Petters, Kreidenweiss)**
  - **supersat. & kappa → crit. radius → CCN / IN**

start with modeling

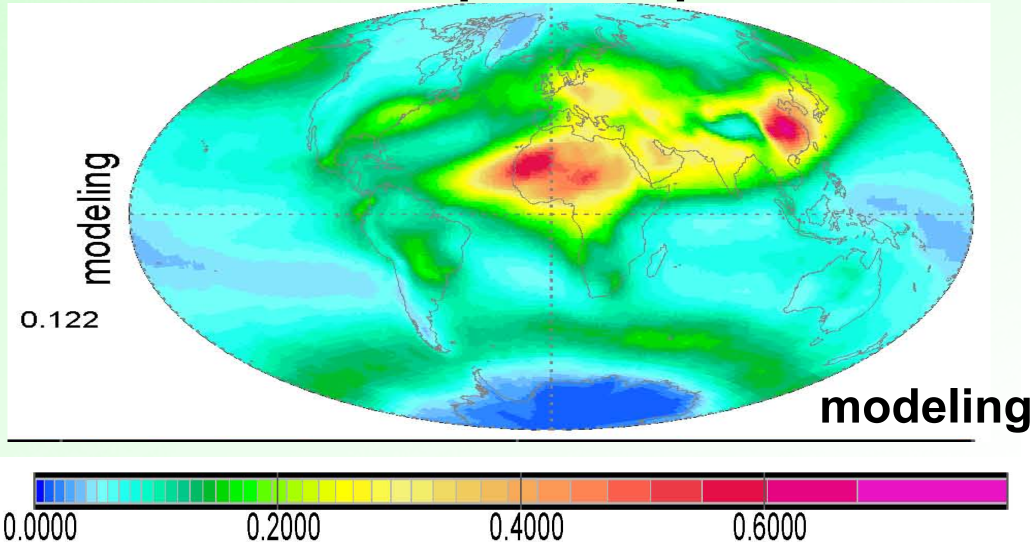
ensemble-median

- advantages
  - complete
  - consistent
  - 'tuned' to satellite patterns
- issues
  - as good as assumptions

all relevant aerosol optical properties

- aerosol optical depth (AOD)
- single scattering albedo
- Angstrom (→ asymmetry factor)

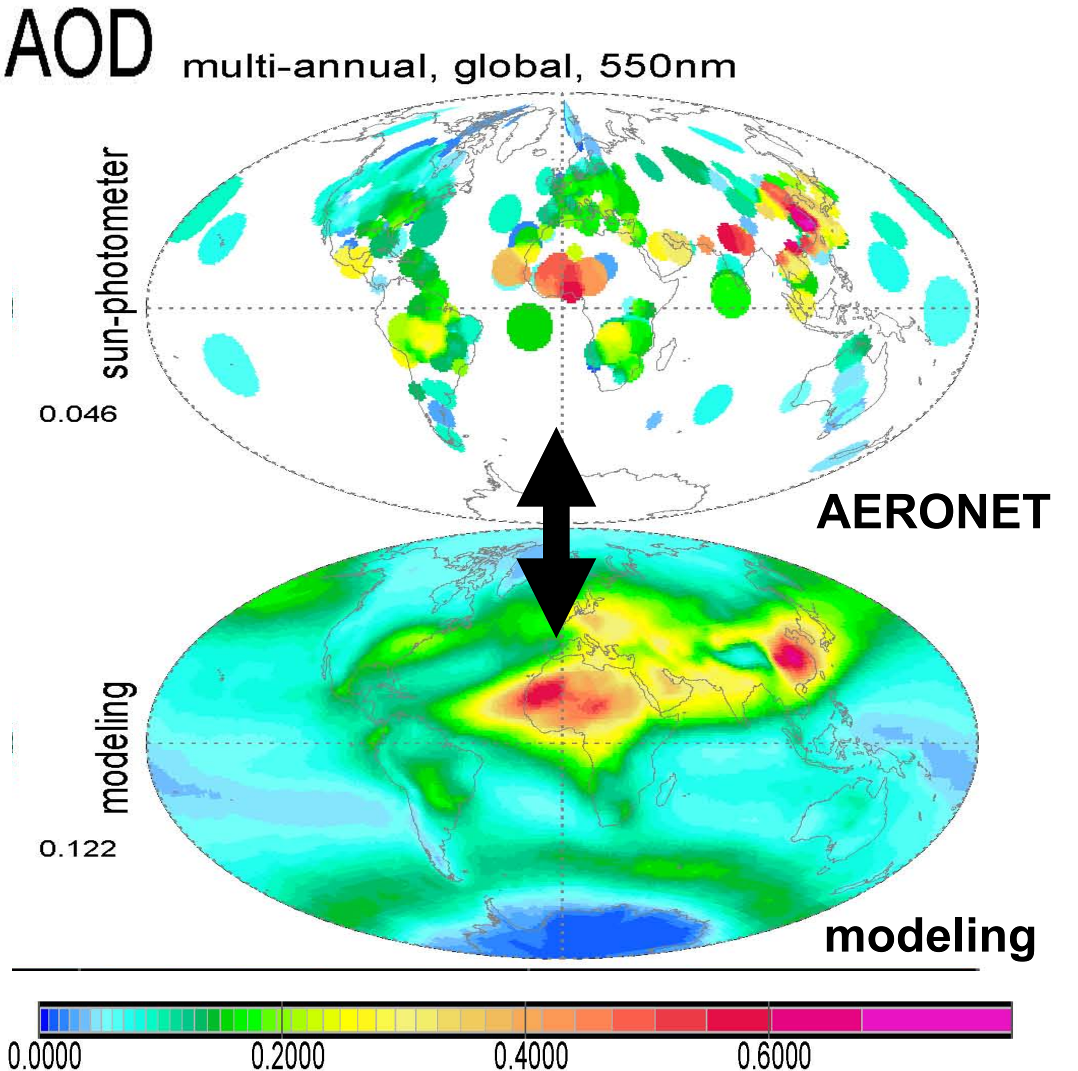
annual aerosol optical depth at 550nm



improve with AERONET data

AERONET

- advantages
  - high quality
- issues
  - local
  - uneven distr.



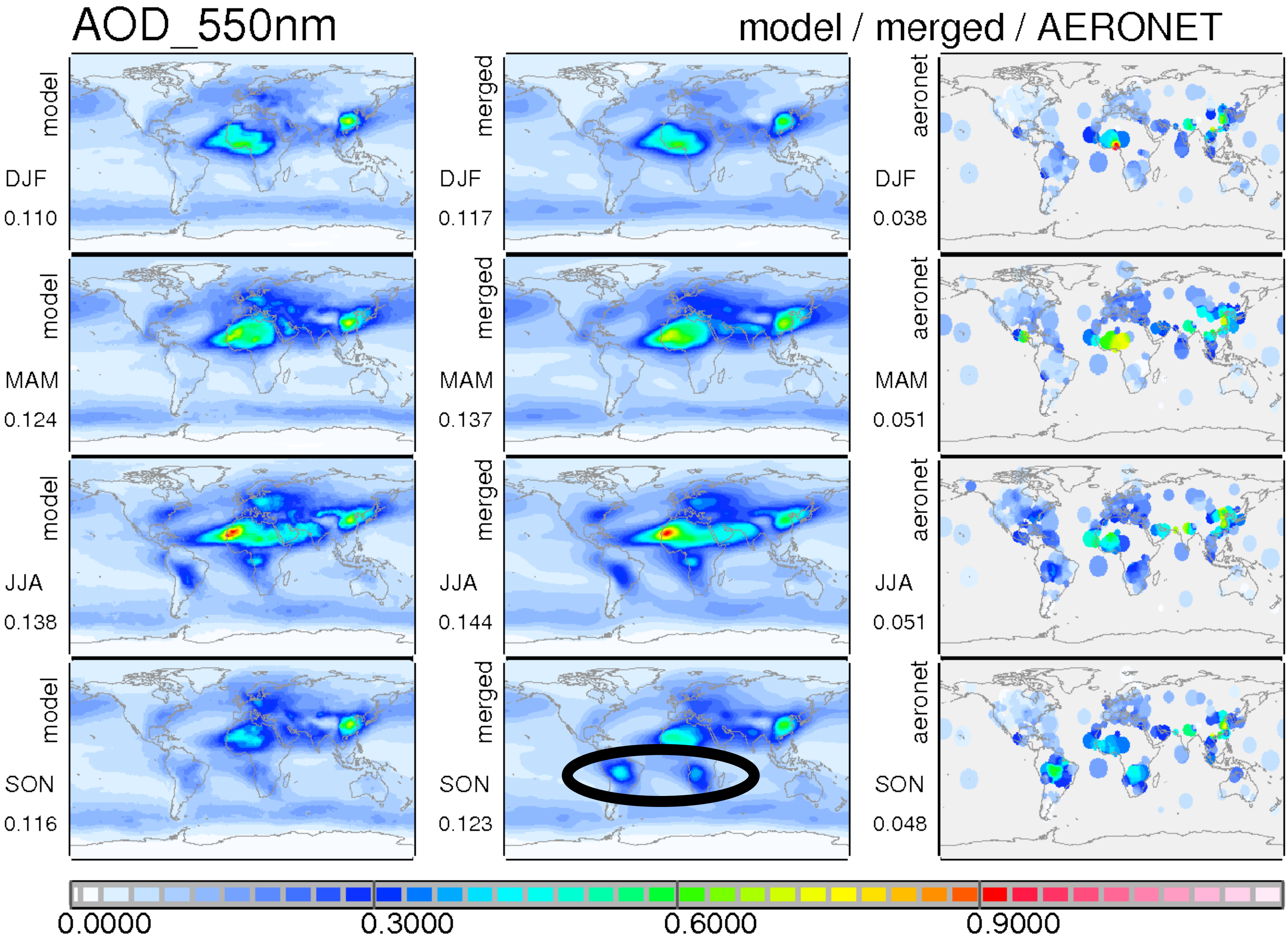
NO satellite data or in-situ data are directly involved

model improvements

- **merging for 3 mid-visible aerosol properties**
  - **AOD** *aerosol opt. depth* **… info on amount**
  - **SSA** *single scatter. albedo* **… info on abs.**
  - **Ap** *Angstrom parameter* **… info on size**

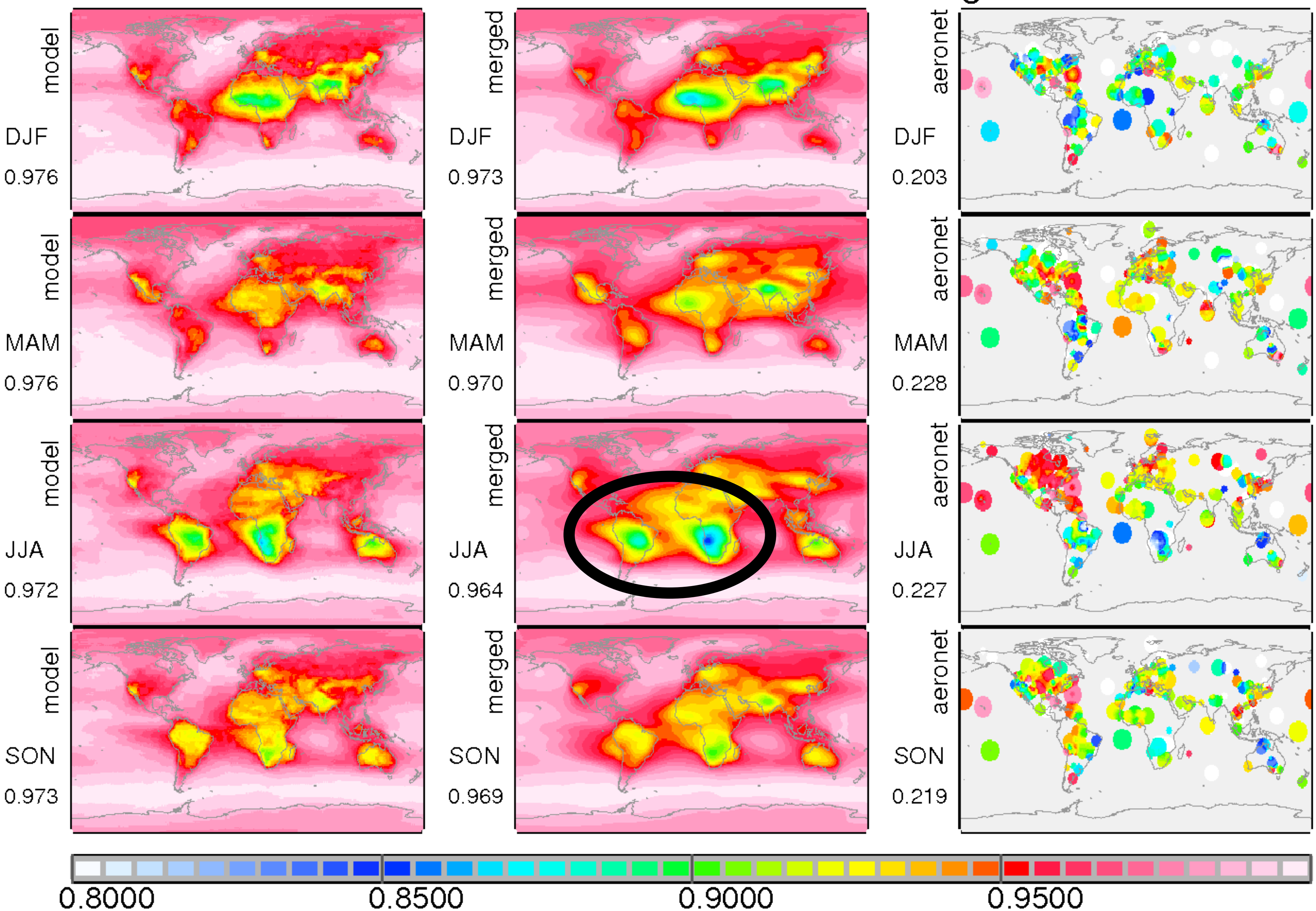
- **improvements indicate general deficiencies in global aerosol component modeling**
  - **lack of AOD** (e.g. SH biomass burning)
  - **missing absorption** (e.g. biomass / pollution)
  - **overestimate size** (e.g. boreal biomass)

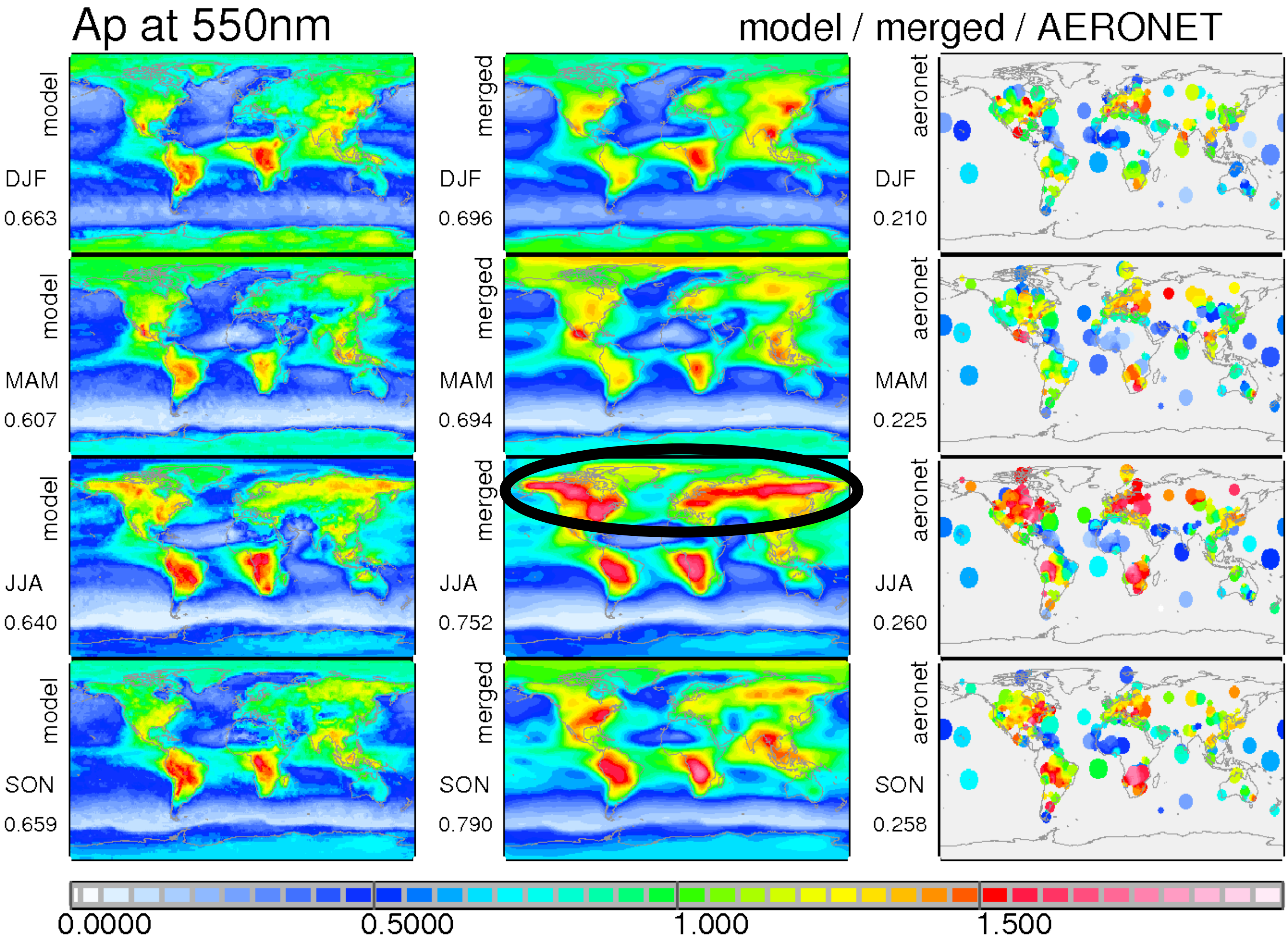
… next: comparison of seasonal maps


AOD_550nm
model / merged / AERONET
model
merged
aeronet
DJF
0.110
0.117
0.038
MAM
0.124
0.137
0.051
JJA
0.138
0.144
0.051
SON
0.116
0.123
0.048
0.0000
0.3000
0.6000
0.9000

SSA at 550nm

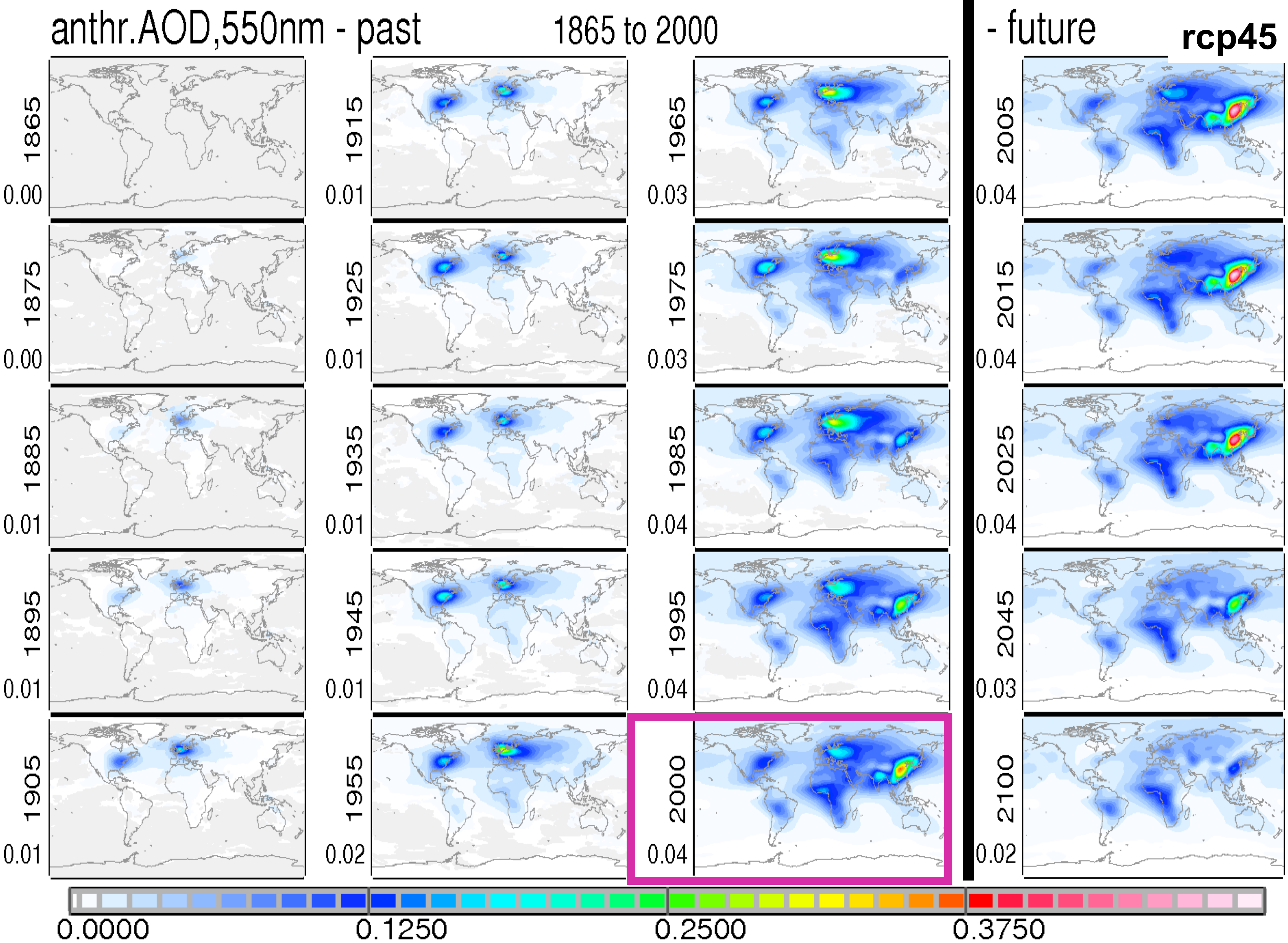
model / merged / AERONET




Ap at 550nm
model / merged / AERONET
model
DJF
0.663
merged
DJF
0.696
aeronet
DJF
0.210
model
MAM
0.607
merged
MAM
0.694
aeronet
MAM
0.225
model
JJA
0.640
merged
JJA
0.752
aeronet
JJA
0.260
model
SON
0.659
merged
SON
0.790
aeronet
SON
0.258
0.0000
0.5000
1.000
1.500

spectral / temp. extension

- use Angstrom parameter to split AOD in
  - AOD, f (fine-mode particles > 0.5μm radius)
  - AOD, c (coarse-mode … part. < 0.5μm radius)
- use modeling to split fine mode AOD (AOD, f) in
  - AOD, f_pre-industrial (AOD,f *yr.1850*)
  - AOD, f_anthropogenic (AOD,f – AOD,f *yr.1850*)
- temporal changes … only for AOD, f_anthrop.
  - coarse mode … no change with time (BAD !)
  - pre-industrial fine … no change with time
  - anthropogenic fine … changes (1860→2100)

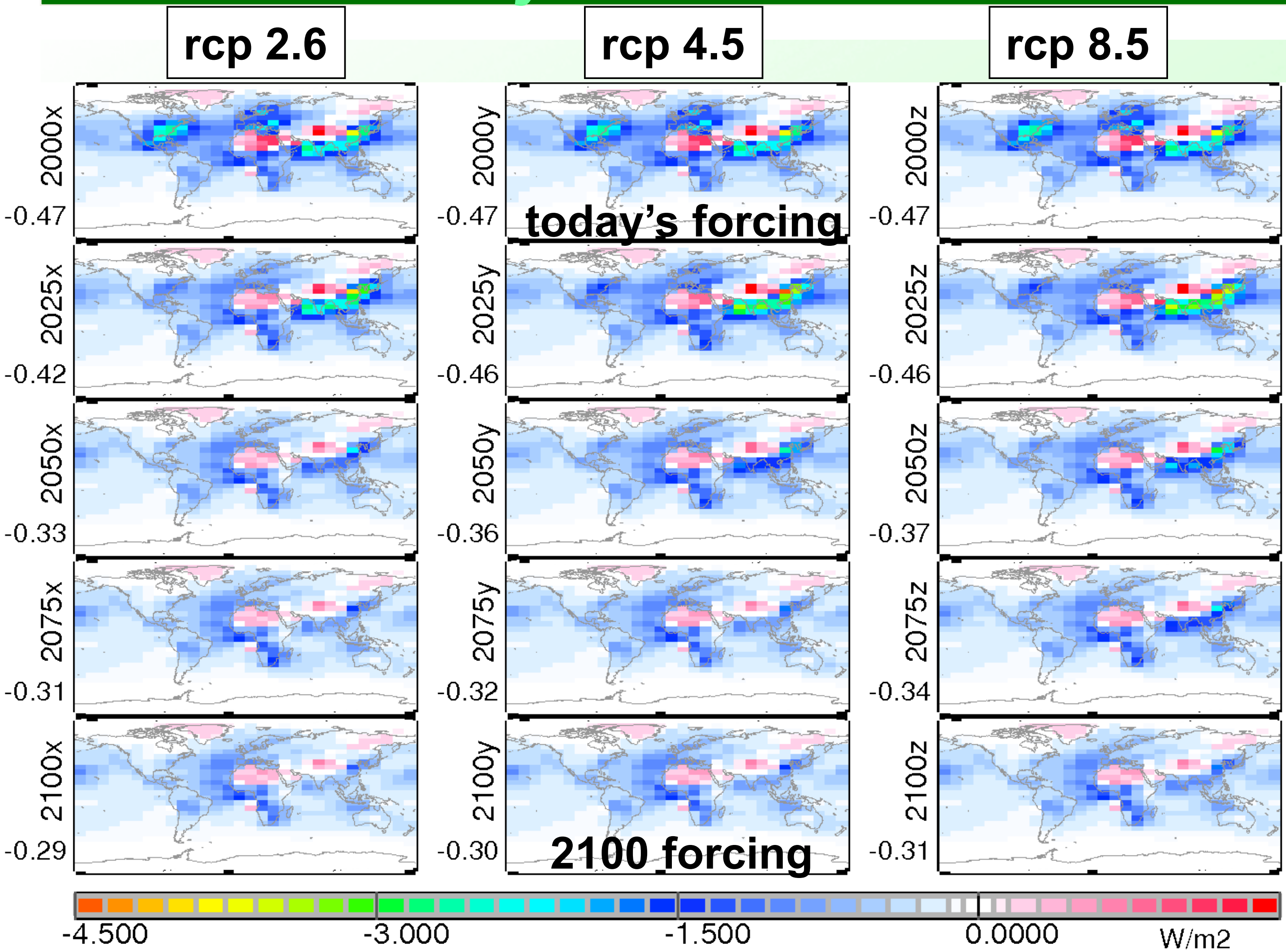

anthr.AOD,550nm - past
1865 to 2000
- future
rcp45
1865
0.00
1875
0.00
1885
0.01
1895
0.01
1905
0.01
1915
0.01
1925
0.01
1935
0.01
1945
0.01
1955
0.02
1965
0.03
1975
0.03
1985
0.04
1995
0.04
2000
0.04
2005
0.04
2015
0.04
2025
0.04
2045
0.03
2100
0.02
0.0000
0.1250
0.2500
0.3750

optimistic forcing futures

- translate temporal changing anthropogenic AOD maps into direct radiative forcing
  - global, annual, at ToA, for all-sky conditions
    - year 1860 0.0 W/m2
    - year 1950 - 0.2 W/m2
    - year 2000 - 0.5 W/m2
    - year 2100 - 0.3 W/m2 (all three RCPs !!)
      - very optimistic views on future direct effects
- anthropogenic is small compared to natural
    - anthropogenic (today) - 0.5W/m2
    - natural (corase & pre-ind) - 1.2W/m2
    - volcanic stratosph. (1992) - 2.0 W/m2

future anthrop – ToA forcing

to reduce by 2100 to about 65% of today's



W/m2	
2000	-0.47
2025	-0.46
2050	-0.37
2075	-0.34
2100	-0.31

what about the indirect effect ?

- an aerosol climatology is more useful with direct connections to cloud- interactions
  - can we associate aerosol anthropogenic change with anthropogenic changes in CCN ?
  - can we provide estimates for IN ?

associated CCN / IN (1)

- AOD → concentrations
  - use altitude distr. to determine extinction (/m)
    - use different altitude distributions for the coarse and fine mode (by modeling / CALIPSO)
  - establish log-normal size-distr. parameters
    - fine-mode
      - std dev.: 1.7 (defines the distribution width)
      - r_{mode} ← $A_{p, fine}$ (defined via 'fine' Angstrom)
    - coarse mode is (pre-)defined (sea-salt or dust)
      - sea-salt: 1.25/1.7 (r_{mode} [μm] / std dev.)
      - dust: 0.93/1.55 (1.23/1.7 1.56/1.85 1.95/2.00 2.31/2.15)
  - assume horizontal homogeneity (1/m → 1/m3)

associated CCN / IN (2)

- assumptions
  - coarse mode concentrations: all CCN
  - coarse mode dust concentration: IN
  - fine-mode concentrations: fraction is CCN
    - only concentrations larger than a critical radius are considered to be CCN
  - anthropogenic (fine-mode) AOD fractions stratify fine-mode CCN into
    - anthropogenic (fine-mode) CCN … and
    - pre-industrial fine-mode CCN …

➔natural CCN (= pre-indust.fine +coarse)

associated CCN / IN (3)

to reduce by 2100 to about 65% of today's

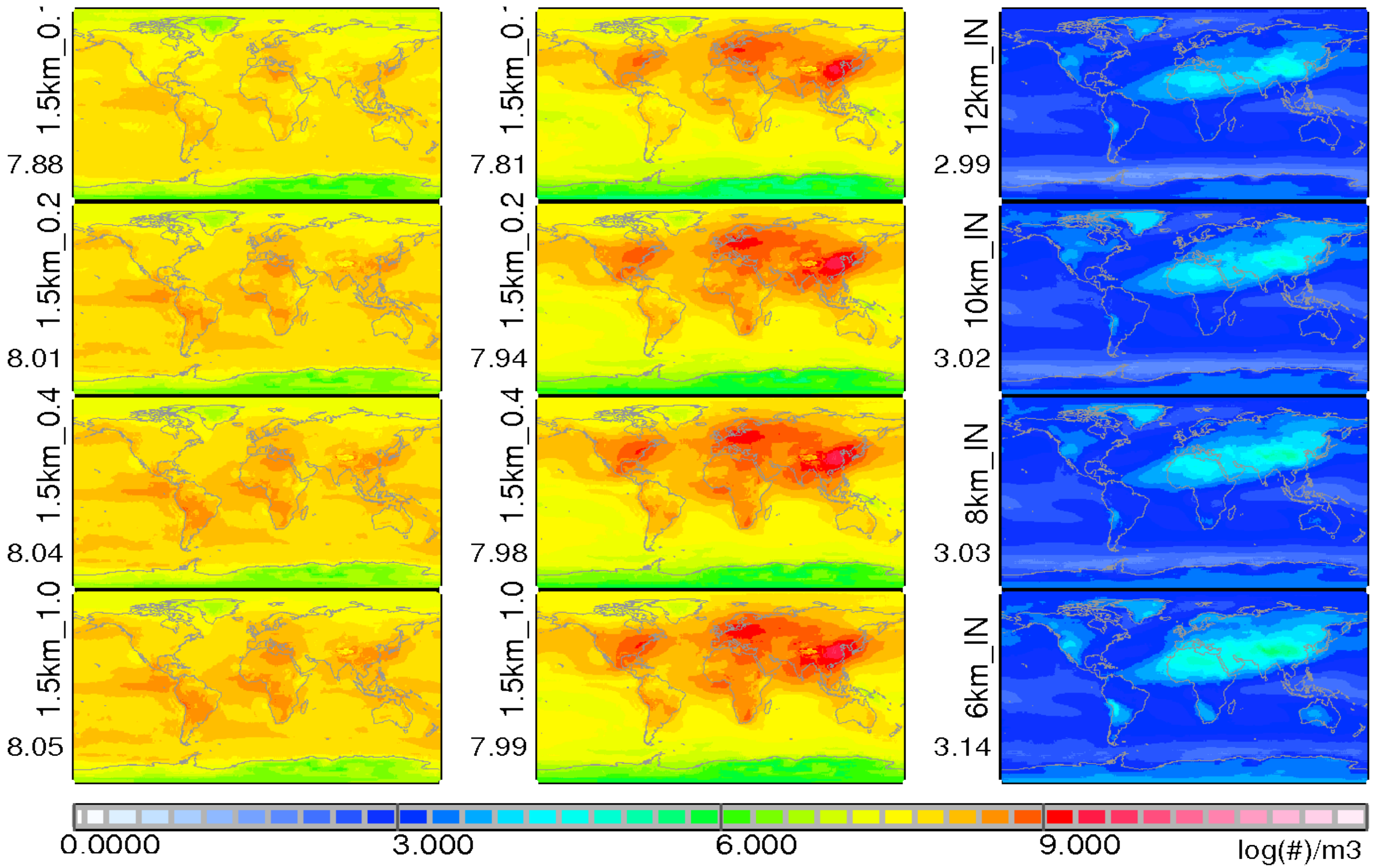
- fine-mode critical cut-off size
  - function of super-saturation [0.05 … 0.20%]
  - function of temperature
  - function of 'kappa' (humidification factor)
    - over oceans near 0.7
    - over continents near 0.4
      - global monthly 1x1 maps of kappa are based on aerosol fine-mode component mass simulations for current aerosol conditions
      - kappa = (1.0*mSS + 0.6*mSU + 0.1*mOC) / (mSS +mSU +mOC +mBC +mDU)
  - compare current nat.CCN / anthrop CCN / IN

CCN at 1.5km above ground & IN (ice nuclei)

anthropogenic CCN concentrations ‘dominate’

- **SS 0.1%**
- **SS 0.2%**
- **SS 0.4%**
- **SS 1.0%**

natural CCN | **anthrop.CCN** | **(dust) IN**



annual yr 2000 concentrations 1.000 1.000.000 1.000.000.000

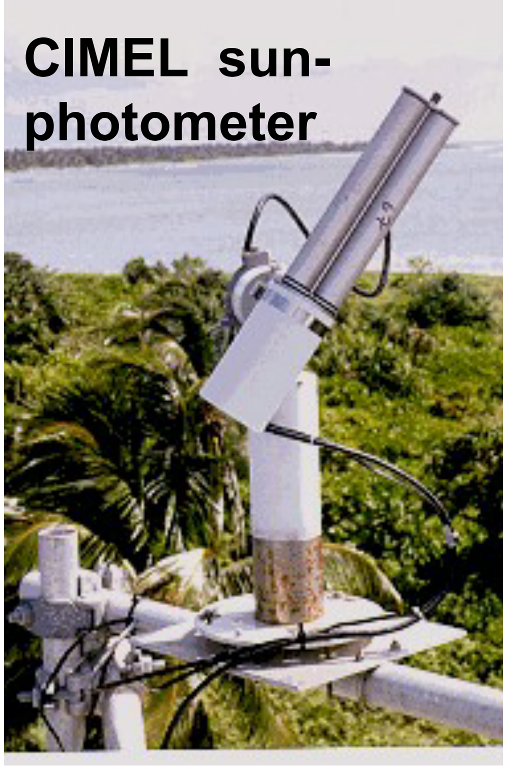
summary

- a new 1x1 monthly aerosol climatology *(yr.2000)*
  - simplified and reasonable … using new INFO
  - all needed opt.properties: AOD, SSA, g … (λ)
- extension in time (anthropogenic change)
  - very general for the direct impact, as the met-influence on natural aerosol is not considered
  - exciting link for the indirect impact, as CCN are extracted and strongly linked to fine-mode
- potential improvements
  - better altitude definition by replacing model estimates with CALIPSO statistics
  - fine-mode dependence on relative humidity
  - better than 1x1 spatial resolution

- **… a longer version**

aerosol climatology

and applications



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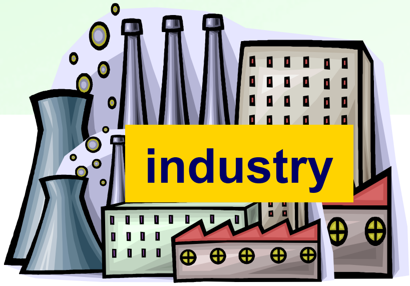
  - many sources
  - short lifetime
  - diff. magnitudes in size
  - changing over time
    - aerosol ←→ clouds
    - aerosol ←→ chemistry
    - aerosol ←→ biosphere
    - aerosol ←→ aerosol

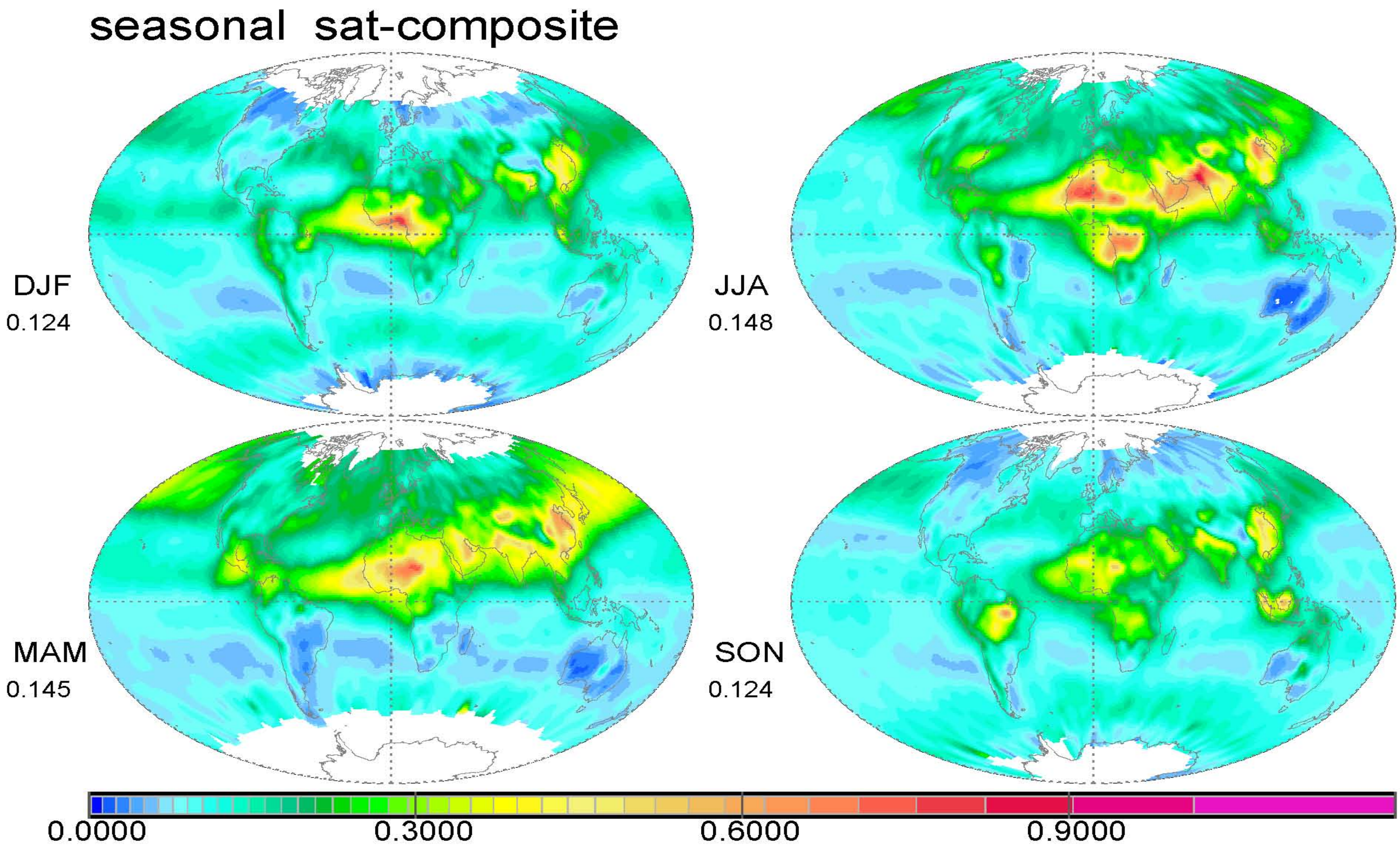
highly variable in space and time !

rapid atmospheric 'cycling'

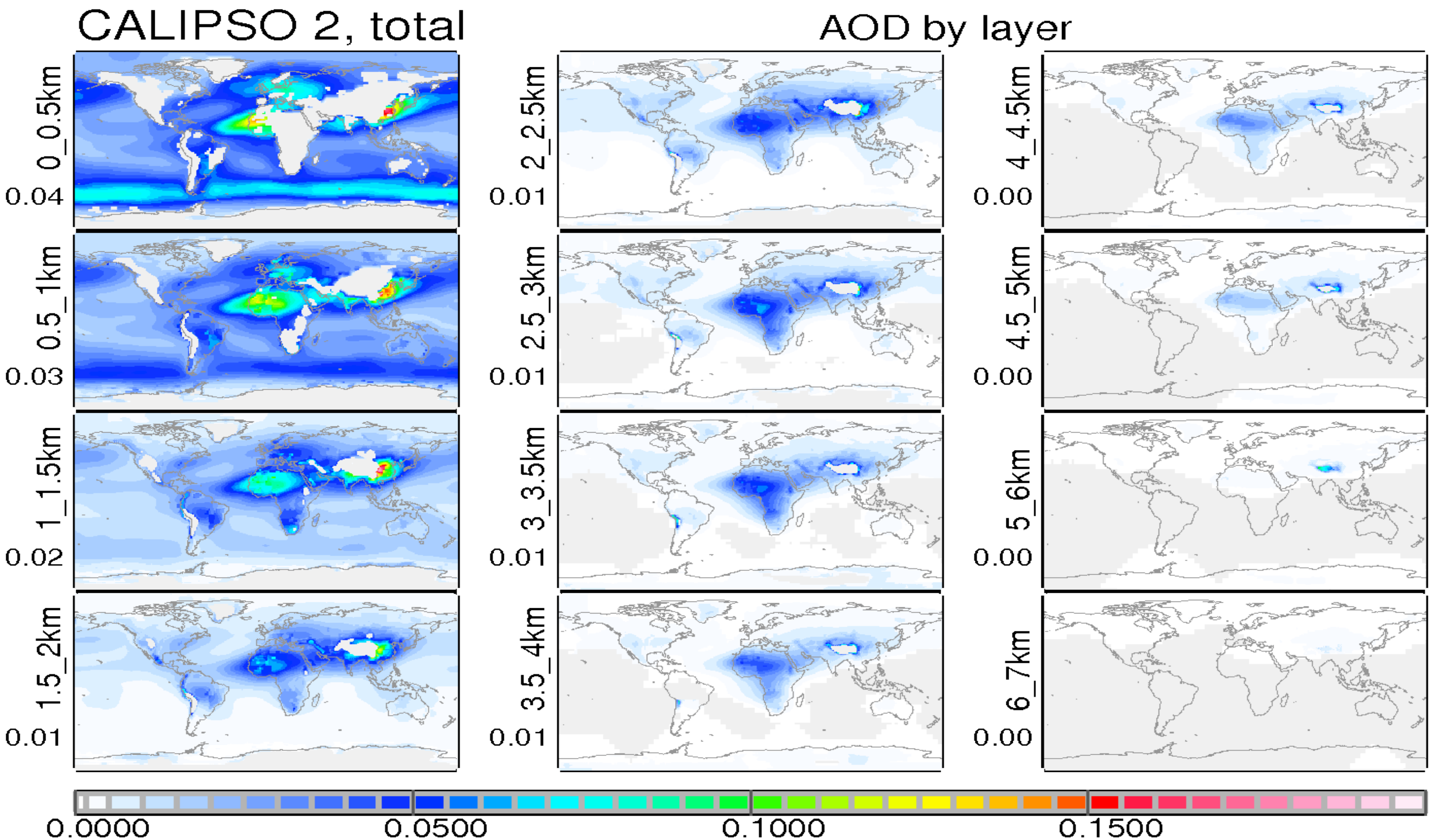


aerosol – its uneven spatial distribution

combining MODIS, MISR, AVHRR data



aerosol – its uneven vertical distribution



most of the tropospheric aerosol is near the surface

aerosol and climate ?

- aerosol (direct) impact on the energy balance
    - reflection of solar energy to space
    - absorption of solar energy (dust, BC, OC)
    - enhancement of IR greenhouse (elev. dust)
- aerosol impact is small compared to cloud imp.

why then all the interest in aerosol ?

- some of the aerosol in anthropogenic added
    - anthrop. aerosol dominates in some regions !
    - aerosol can serve as nuclei for cloud and can affect clouds, precipitation and hydro.cycle !

simulating aerosol = $$$

- complex aerosol modules exist (e.g. Sprintars)
- they are useful … but often too expensive

the ECHAM/HAM aerosol modules carries 27 tracers !

optically active and relevant sizes

Hamburg Aerosol Module (HAM) [Stier et al., ACP, 2005]

MODES IN M7	SOLUBLE/MIXED	INSOLUBLE
NUCLEATION ($r < 0.005$ μm)	1 N_1, M^1_{SO4}	
AITKEN (0.005 μm $< r < 0.05$ μm)	2 N_2, M^2_{SO4}, M^5_{BC}, M^9_{OC}	5 N_5, M^8_{BC}, M^{12}_{OC}
ACCUMULATION (0.05 μm $< r < 0.5$ μm)	3 N_3, M^3_{SO4}, M^6_{BC}, M^{10}_{OC}, M^{13}_{SS}, M^{15}_{DU}	6 N_6, M^{17}_{DU}
COARSE (0.5 μm $< r$)	4 N_4, M^4_{SO4}, M^7_{BC}, M^{11}_{OC}, M^{14}_{SS}, M^{16}_{DU}	7 N_7, M^{18}_{DU}

size →

- Two-moment aerosol scheme that predicts mass and number concentrations of sulfate (SO4), black carbon (BC), particulate organic matter (OC), mineral dust (DU) and sea salt (SS)
- → Total of 27 prognostic equations

how to simplify ?

… for tropospheric aerosol

- use an aerosol **climatology**, which gives
  - aerosol radiative properties
    - AOD, SSA, g … at all needed wavelengths
    - separately for coarse and fine mode
  - aerosol AOD anthropogenic fraction (time)
    - fraction of fine mode than is anthropogenic
  - aerosol altitude distribution
  - CCN concentration
    - to maintain a link to clouds

climatology

- monthly 1x1 (lat/lon) resolution
  - compose one typical current year (year 2000)
    - median of 15 AeroCom models (no extremes)
    - enhance with quality AERONET data
- extend spectrally
- use simulation to scale back/forward in time
- add altitude information (modeling or CALIPSO)
- add information for associated CCN and IN
- some application: … direct aero forcing in time

start with modeling

ensemble-median

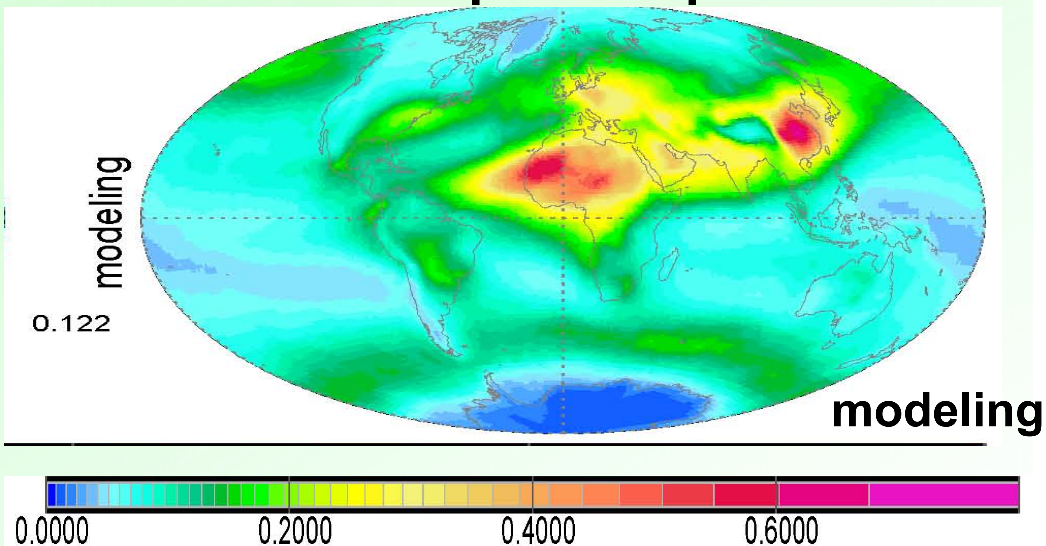
- **advantages**
  - complete consistent (no data-gaps)
- **issues**
  - as good as assumptions

although usually 'tuned' to sat AOD observations

all relevant aerosol optical properties

- aerosol optical depth (AOD)
- single scattering albedo
- Angstrom (→ asymmetry factor)

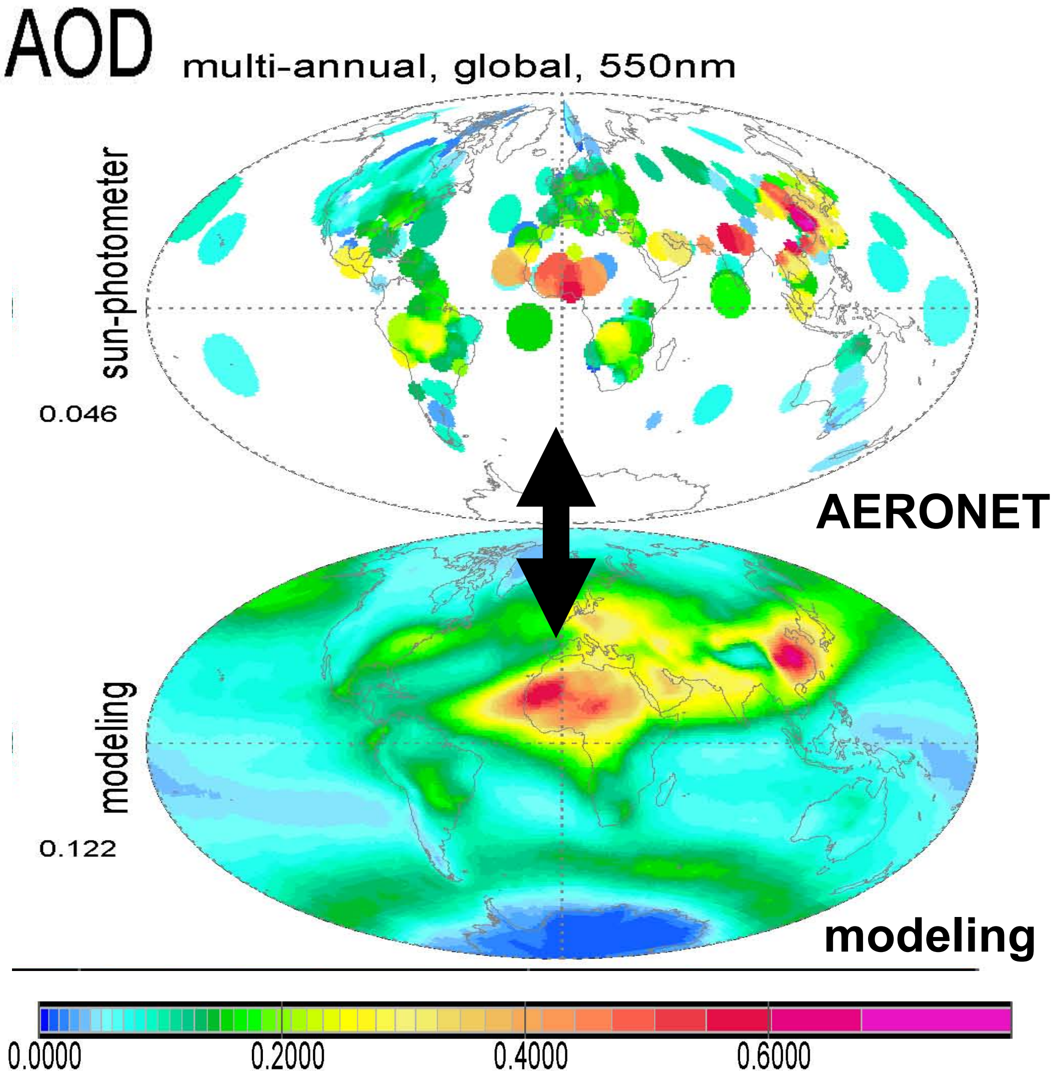
annual aerosol optical depth at 550nm



improve with AERONET data

AERONET

- advantages
  - high quality
- issues
  - local
  - global uneven

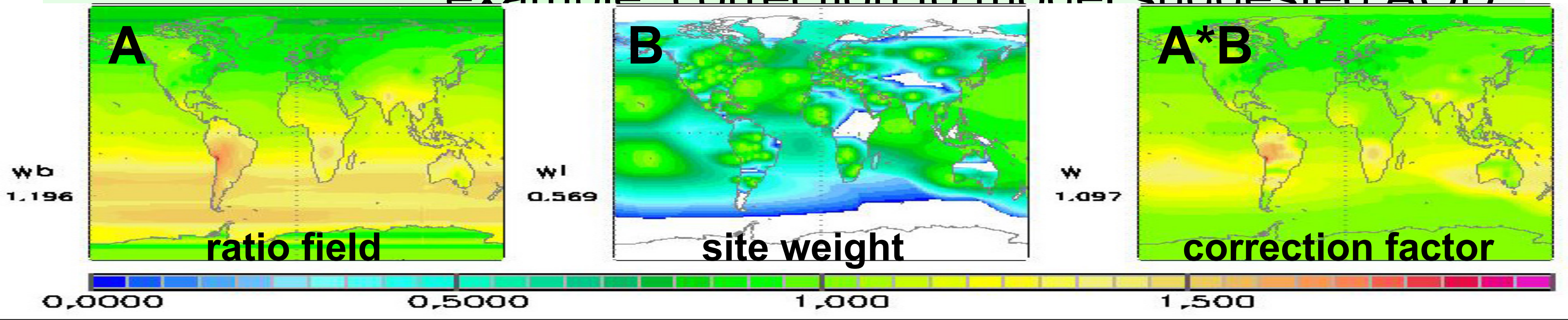


note, the climatology does NOT use satellite or in-situ data, they only constrain global modeling

the merging

- combine point data on regular grid (1°x1° lon/lat)
  - extend spatial influence of identified sites with better regional representation
- spatially spread valid grid ratios and combine
  - decaying over +/- 180 (lon) and +/- 45 (lat)
- apply ratio field values (A) at site domains with distance decaying weights (B) → corr. factors

example: correction to model suggested AOD

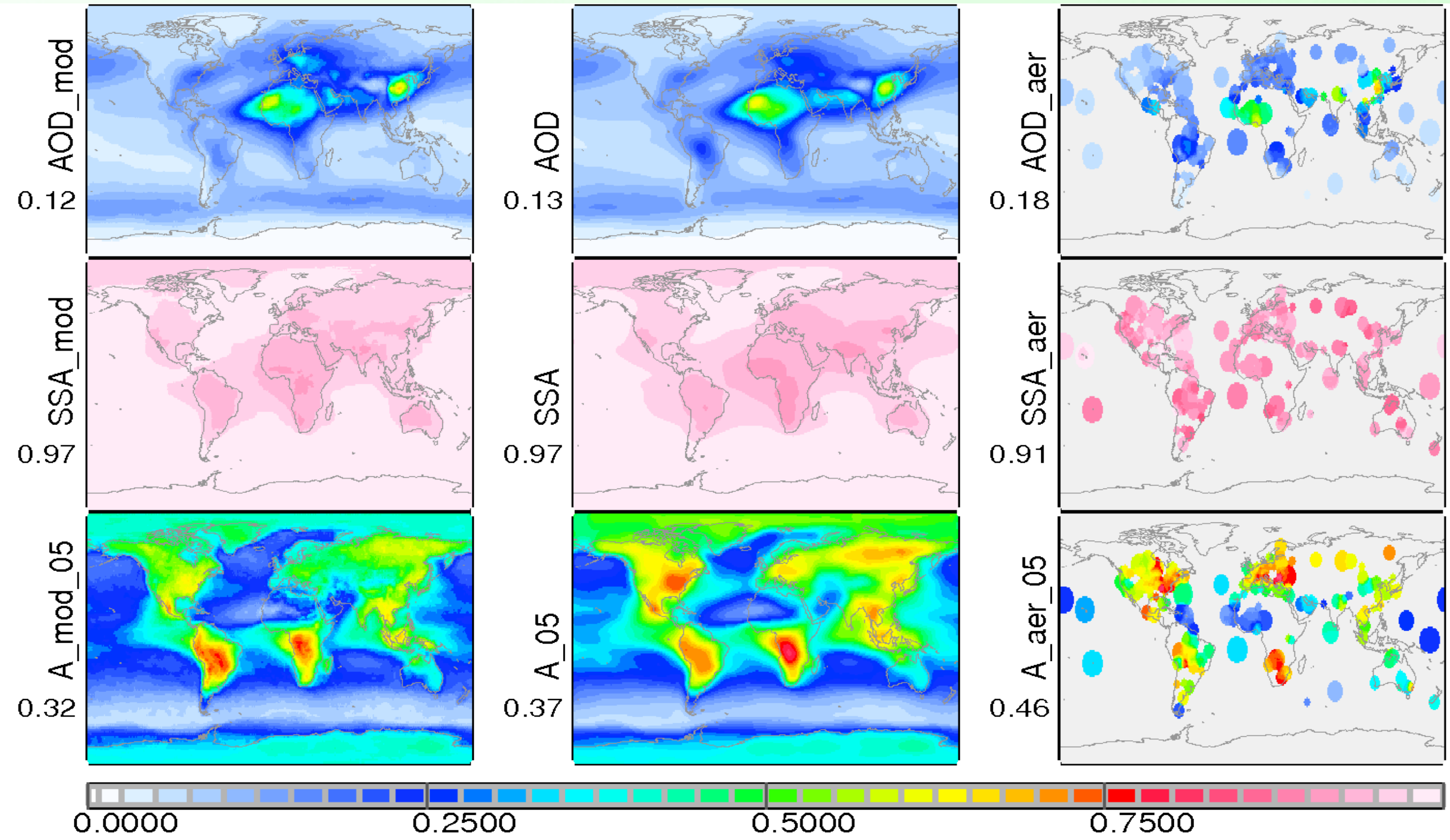


merging results

model → **merged** **←AERONET**

0.55µm

- **AOD**
- **SSA**
- **Ang**



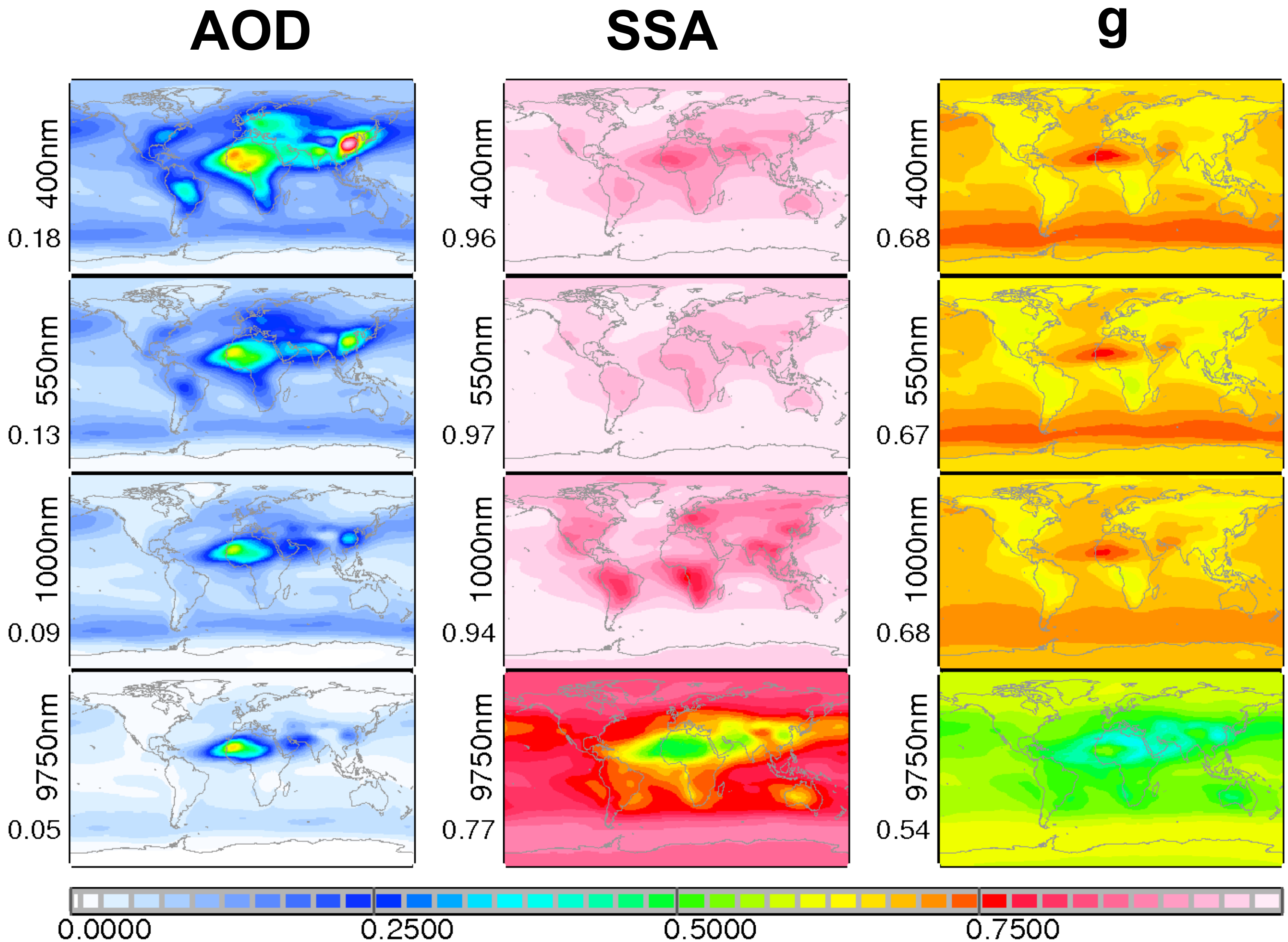
'merged' compared to 'global modeling':
AOD larger, absorption stronger, particles smaller

spectral extension

- use the Angstrom to stratify AOD into
  - AOD, f (fine sizes > 0.5μm radius, *Ap =2.2-1.7*)
  - AOD, c (coarse particles < 0.5μm rad., *Ap=0*)
- use SSA to establish dust size
  - dust is larger when fine SSA would fall below pre-scribed threshold
- coarse mode spectral dependence is defined
  - composition and size was assigned
- fine mode spectral dependence only for solar
  - Ap, f define AOD, f spectral dependence
  - g (from Angstrom) and SSA drop in near-IR

spectral samples – annual avg maps

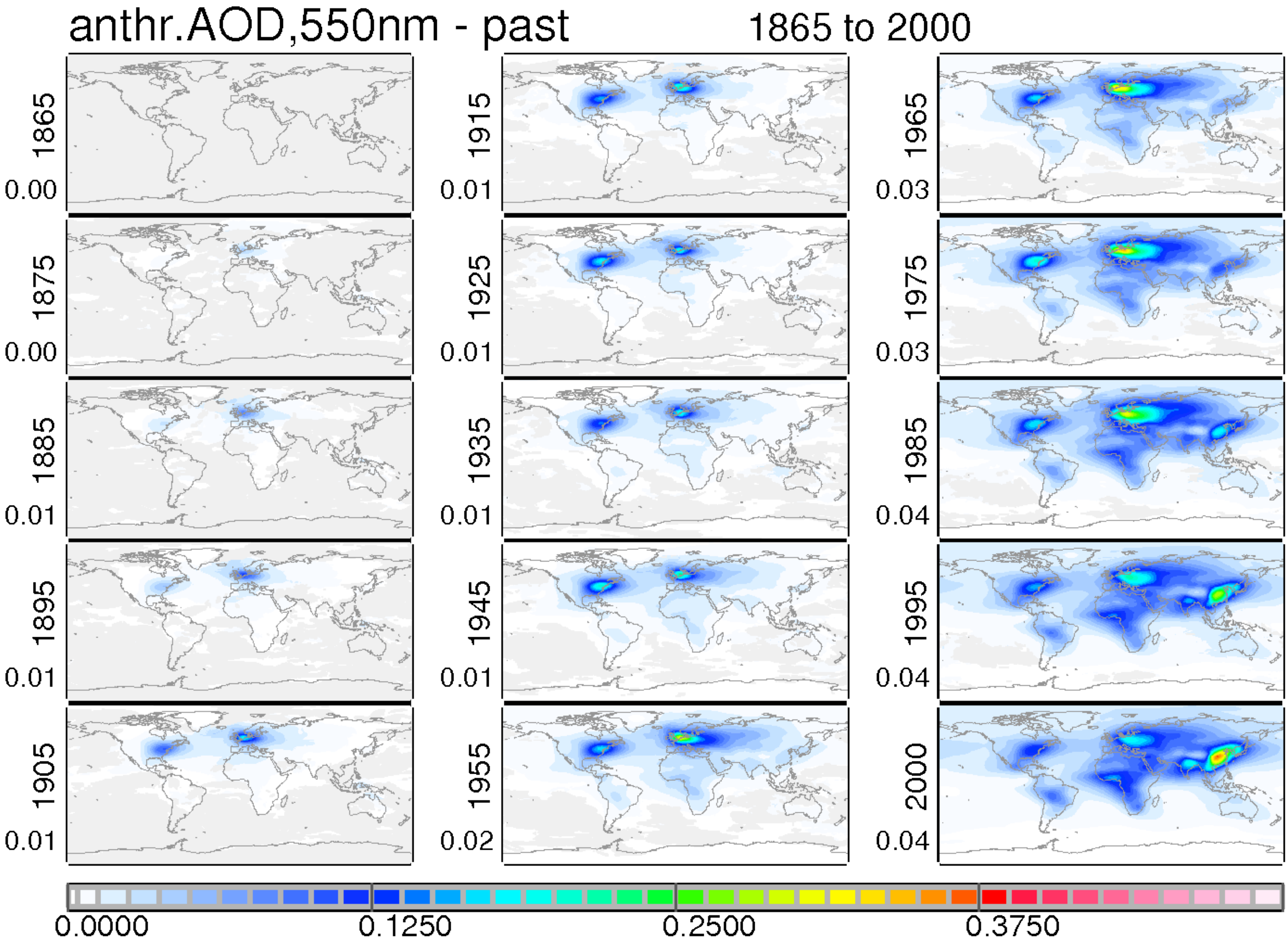
- **UV 0.4μm**
- **VIS 0.55μm**
- **n-IR 1.0μm**
- **IR 10μm**



extension in time

- components that DO NOT change with time
  - coarse mode
  - pre-industrial fraction of fine mode
    - use info on what is ‘anthropo’ from modeling

- components that DO changes with time
  - stratospheric aerosol
  - anthropogenic fraction of the fine mode
    - back: ECHAM simulation with NIES emissions
    - forward: ECHAM runs with rcp scenarios


anthr.AOD,550nm - past
1865 to 2000
1865
0.00
1875
0.00
1885
0.01
1895
0.01
1905
0.01
1915
0.01
1925
0.01
1935
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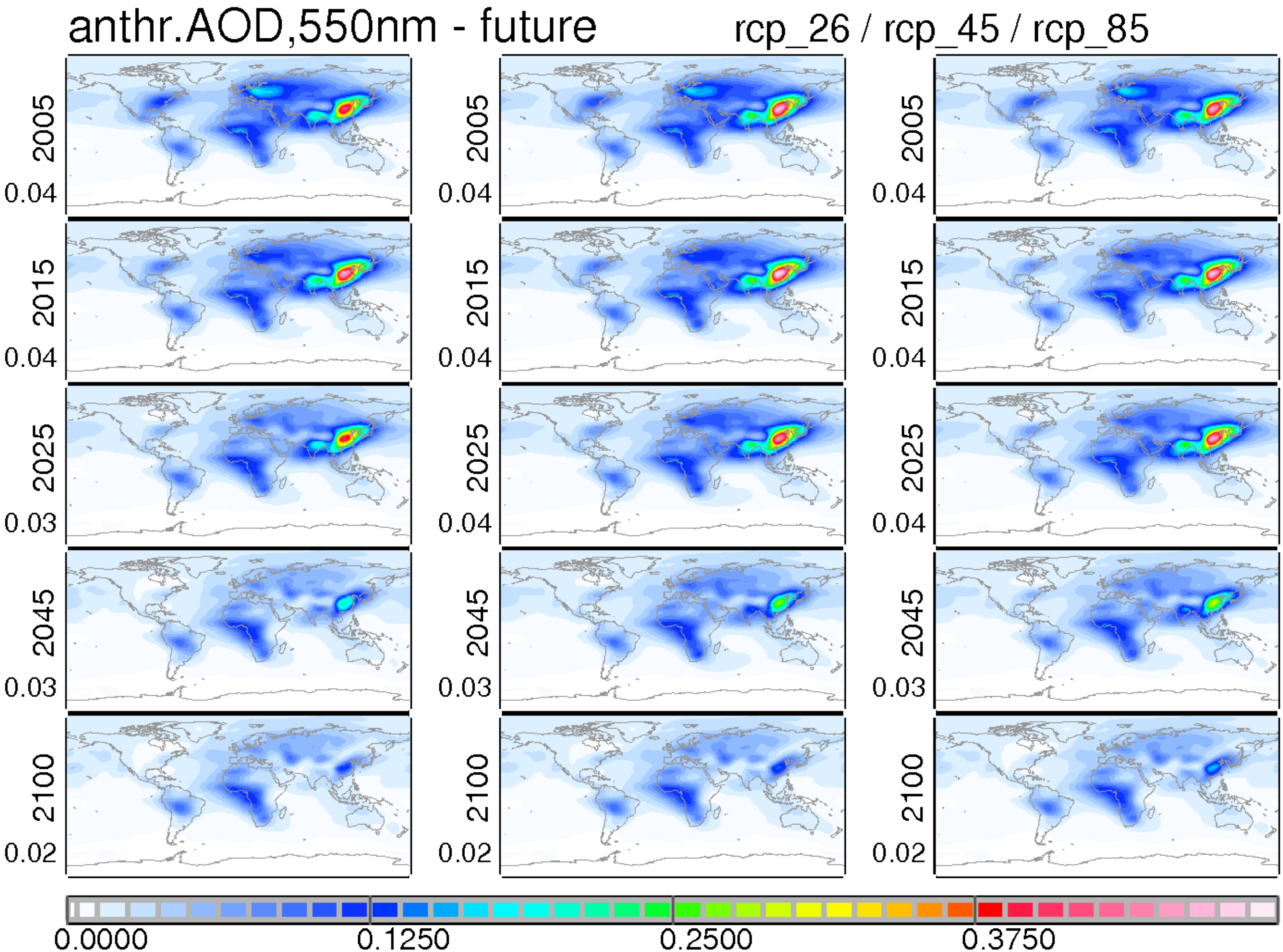
0.0000
0.1250
0.2500
0.3750


anthr.AOD,550nm - future
rcp_26 / rcp_45 / rcp_85
2005
0.04
2015
0.04
2025
0.03
0.04
2045
0.03
2100
0.02
0.0000
0.1250
0.2500
0.3750

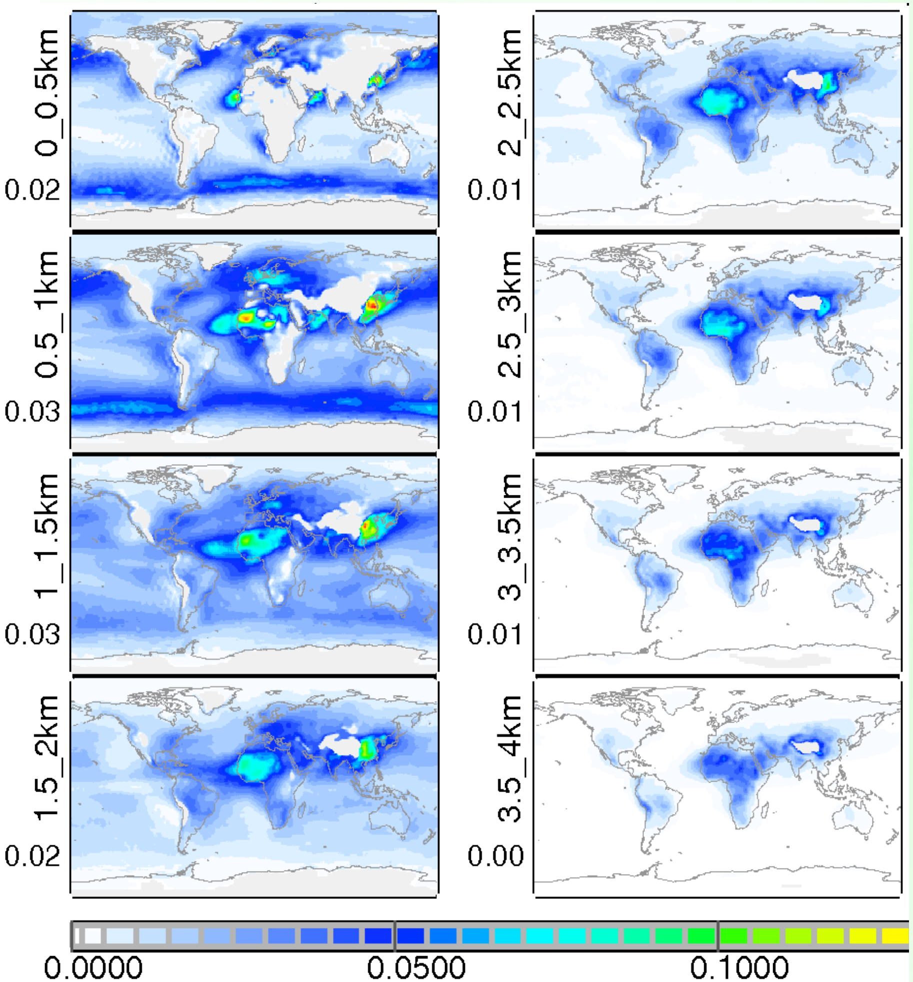
altitude

- current distributions
  - total aerosol
    - CALIPSO version 2
    - ECHAM
  - Separately for fine and coarse mode
    - ECHAM

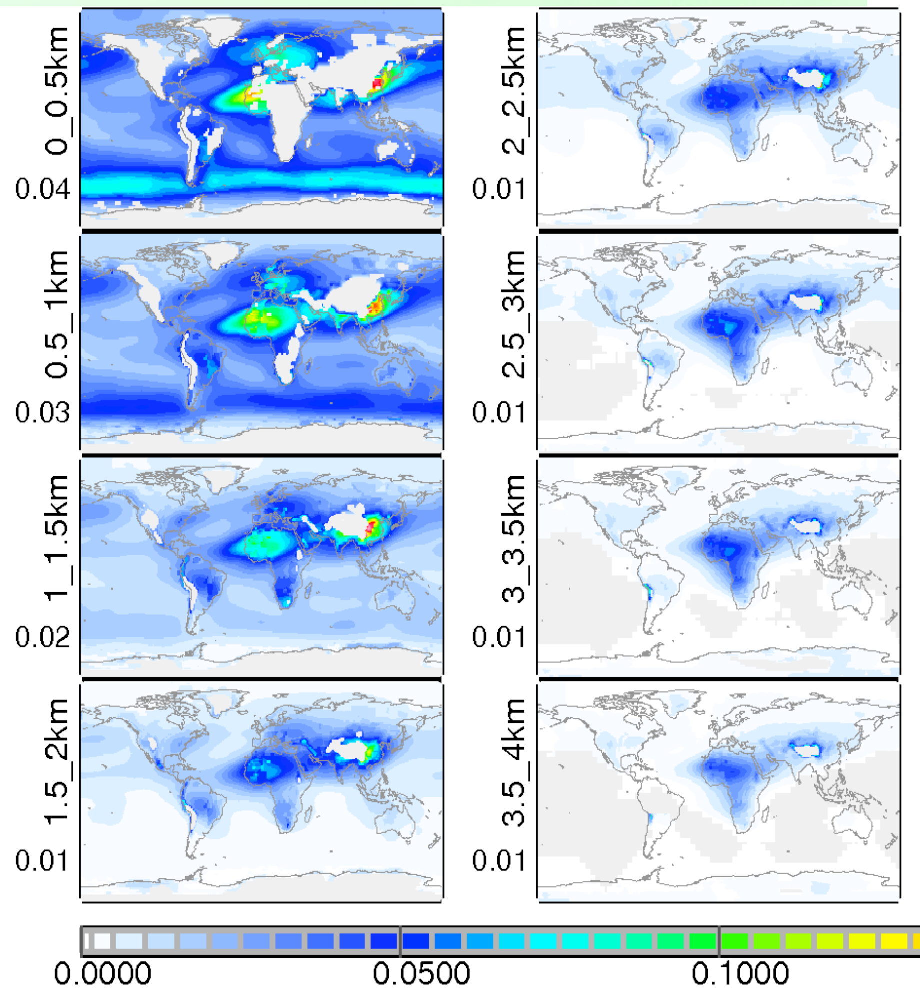
- next … CALIPSO version 3
    - use (non-sphere) (=dust) for coarse
    - use total-(non-sphere) for fine

total AOD (550nm) by layer

ECHAM 5 / HAM *(model)*



CALIPSO vers.2 *(obs)*



link to clouds

- aerosol provide CCN and IN to clouds
  - changes to aerosol concentration can modify cloud properties and the hydrological cycle
  - critical parameters are
    - aerosol concentration ← from climatology
    - aerosol composition ← from modeling
    - super-saturation
    - temperature

CCN – need concentrations, not column data

- aerosol concentrations

  …are defined by the AOD vertical distribution and assumed log-normal size-distributions

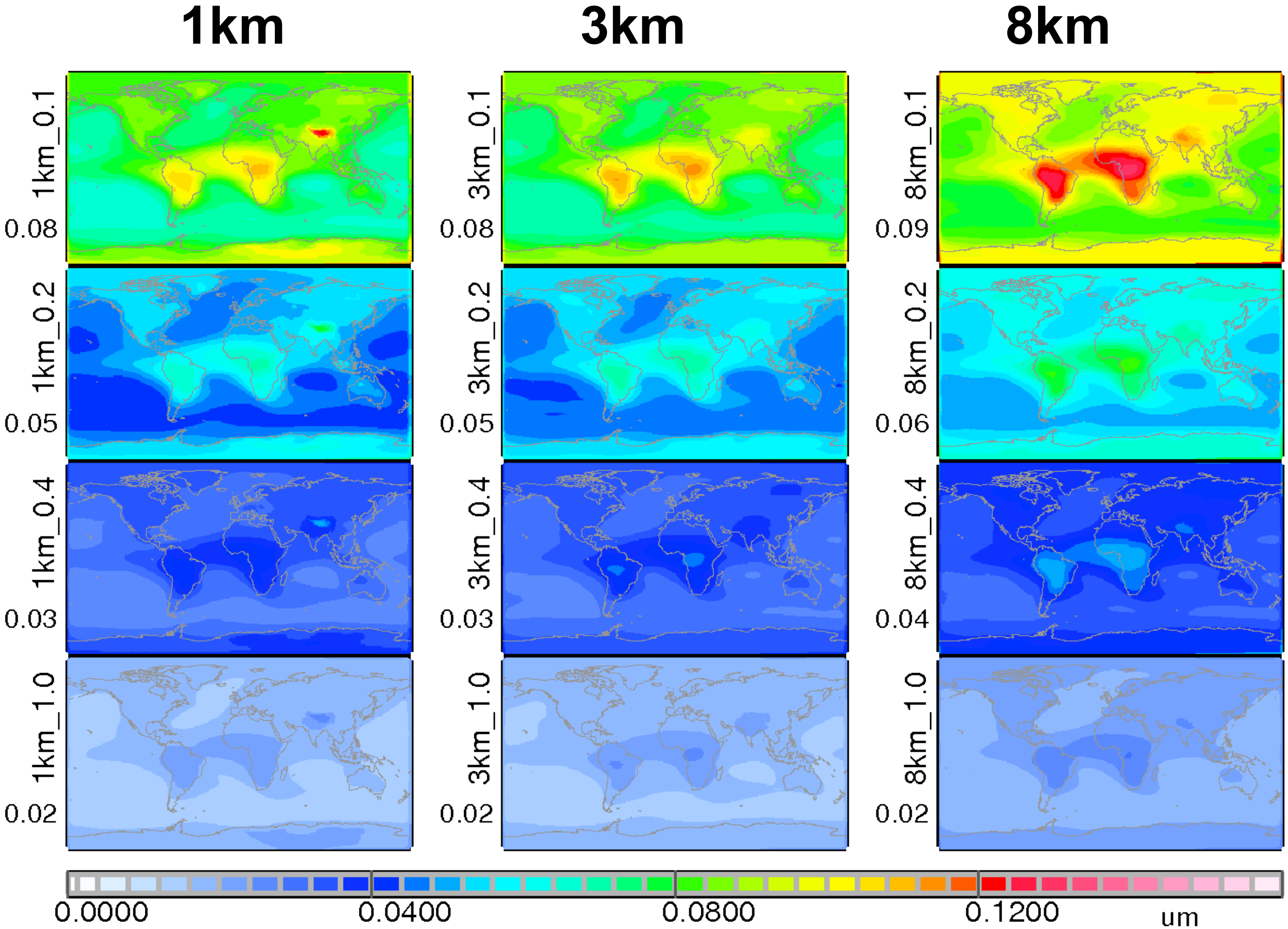
  - coarse-mode log-normal properties for sea-salt or dust are prescribed
  - fine-mode log-normal width is fixed (std.dev 1.7) and the mode radius is linked to the Angstrom of the fine-mode (which depends on low cloud cover)
    - larger aerosol radii at moister conditions
    - smaller aerosol radii at drier conditions

define CCN / IN

- all coarse mode particles are CCN … plus
- a fraction of fine-mode particles are CCN
  - for fine-mode concentrations:
    - a critical cut-off size is determined as function
      - super-saturation
      - kappa (‘humidification’) - maps are based on ECHAM/HAM simulations for fine-mode AOD
        - » kappa weights: SS =1.0, SU =0.6, OC =0.1, DU/BC =0)
    - only sizes larger that the cut-off are considered as fine-mode CCN
- coarse mode dust particles are IN

critical fine-mode radius

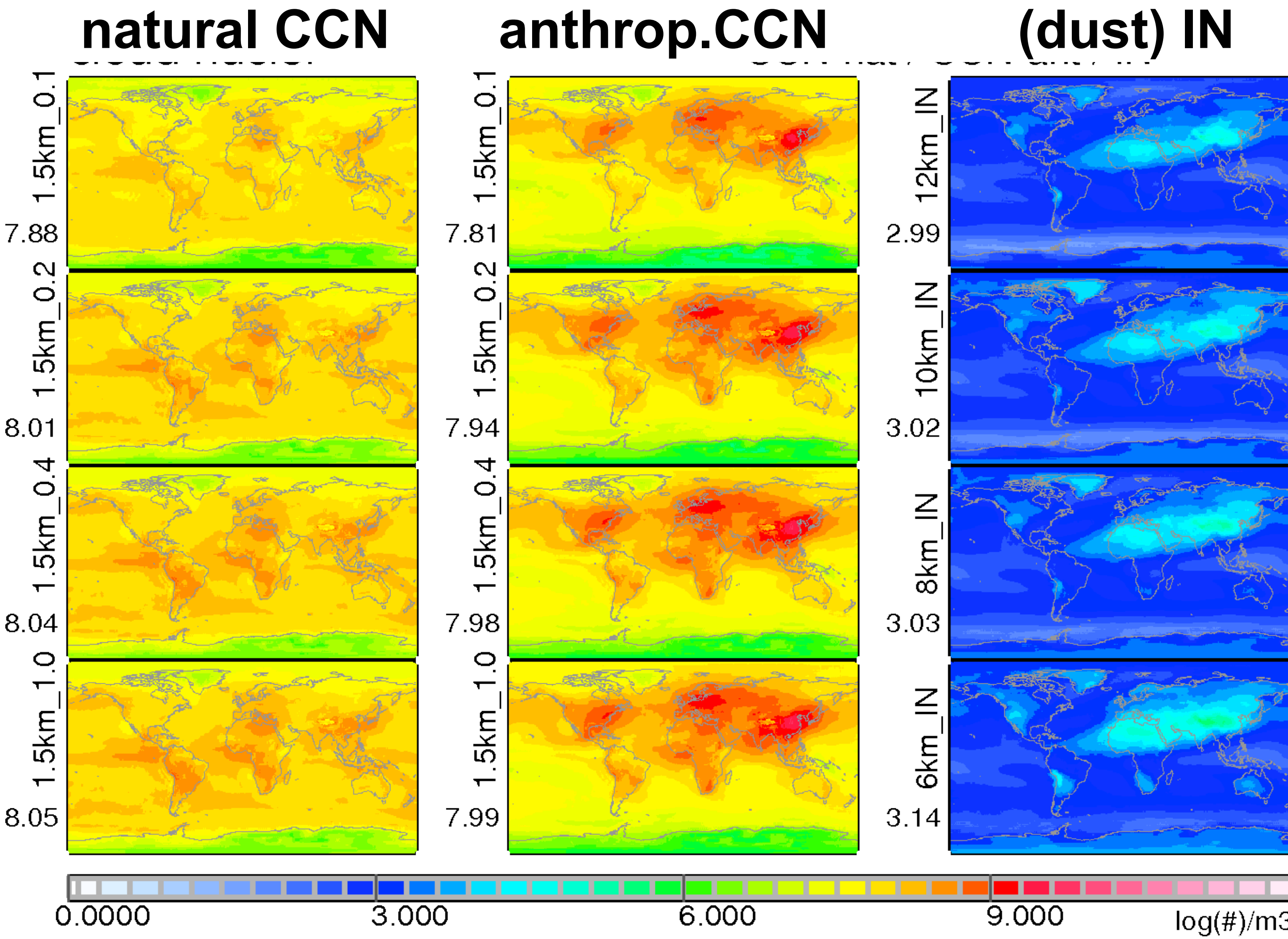
- **SS 0.1%**
- **SS 0.2%**
- **SS 0.4%**
- **SS 1.0%**



CCN at 1.5km above ground & IN (ice nuclei)

anthropogenic CCN concentrations 'dominate'

- **SS 0.1%**
- **SS 0.2%**
- **SS 0.4%**
- **SS 1.0%**



application – aerosol direct rad.forcing

- apply climatology in an off-line rad. transfer code for aerosol direct radiative forcing/effects
- focus on aerosol direct anthropogenic impact
  - current impact against natural impact(s)
  - changes in time (from 1875 to 2100)
- ‘global’ vs (‘Mediterranean’ or) ‘E.Asia’ impacts
- some results
  - natural impacts dominates
  - by 2100 - global forcing at 1970 levels
  - by 2100 - mediterranean forcing at 1910 levels
  - by 2100 - E.Asia forcing at 1975 levels

radiative forcing

- the impact on the distribution of rad. energy …
  - on the solar radiation (0.2 - 3.5 μm)
  - on the terrestrial radiation (3.5 - 100μm)
- … at the top of the atmosphere (ToA)
  - climate relevance: impact on the entire Earth-atm-System: loss = cooling gain = warming
- … at the surface
  - impact on surface temperature and processes (e.g. evap): loss = colder T gain = warmer T

aerosol radiative forcing

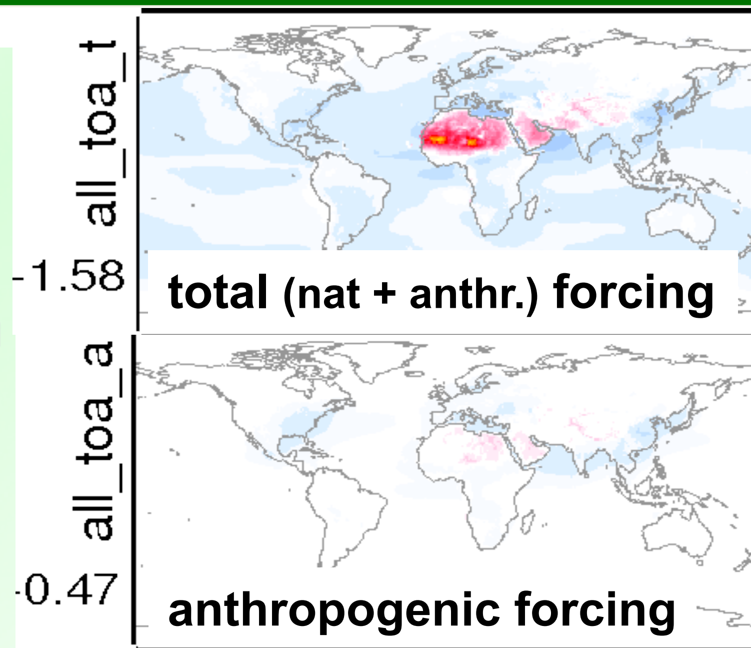
- impacts on the distribution of rad. energy …
  - direct: by the presence of (added) aerosol
    - mainly a solar radiative (daytime) impact
  - indirect : *(not covered)* by modifying other atm properties which cause a forcing of their own
    - changing cloud microphysics / cloud lifetime
- … at the top of the atmosphere (ToA)

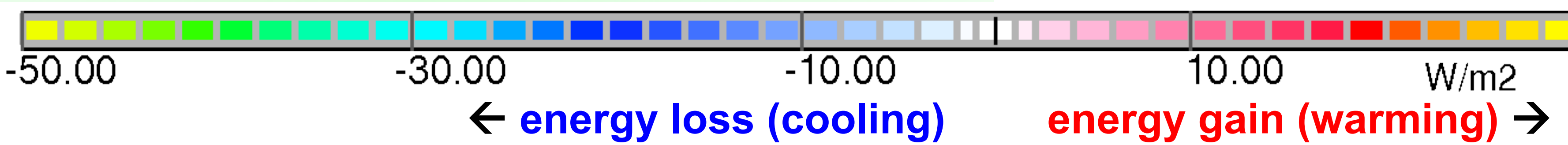
compare to +2.8 W/m2 by anthrop greenh gases

aerosol direct forcing – ToA

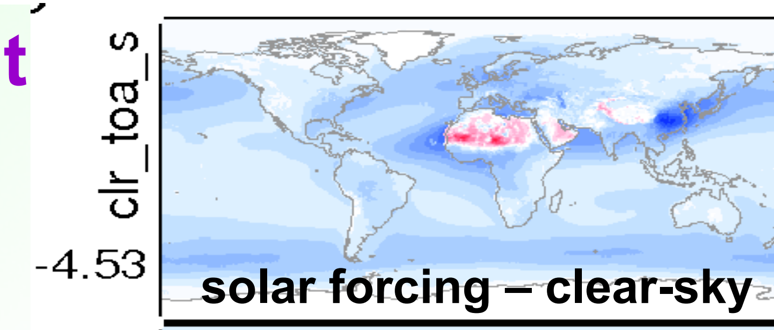
70% of today's ToA aerosol forcing is natural

- **aerosol** on average "**cools**"
  - **global avg: - 1.6 W/m2**
  - **highly variable, even sign**
  - **anthrop. impact is much smaller: - 0.5 W/m2**





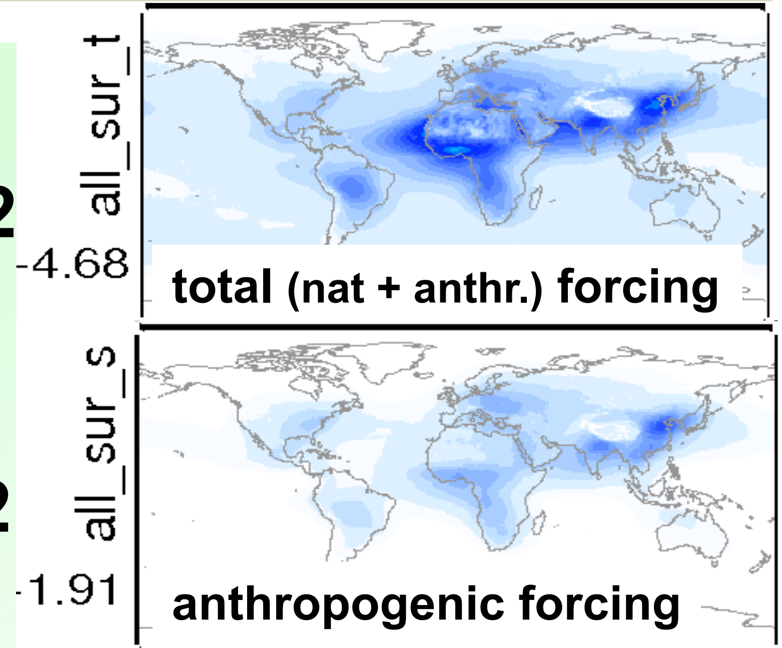
  - *but* **large values of instant and by satellite remote sensing can confuse**

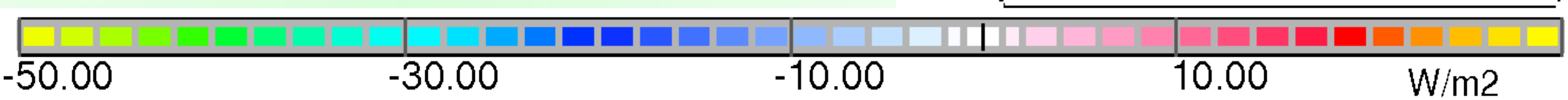


aerosol direct forcing – surface

60% of today's surface aerosol forcing is natural

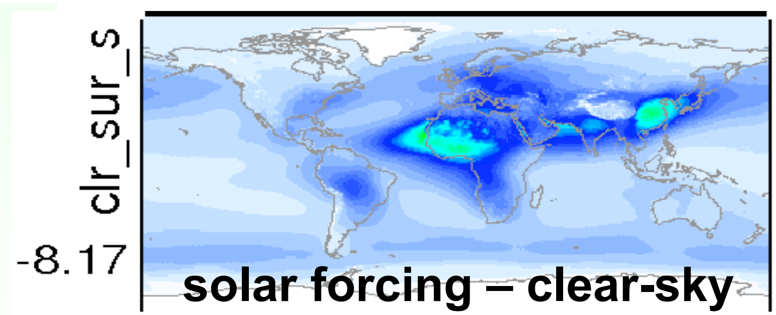
- aerosol always "cools"
  - global average: **- 4.7W/m2**
  - variable, source related
  - anthropogenic forcing is less than half: **- 1.9 W/m2**





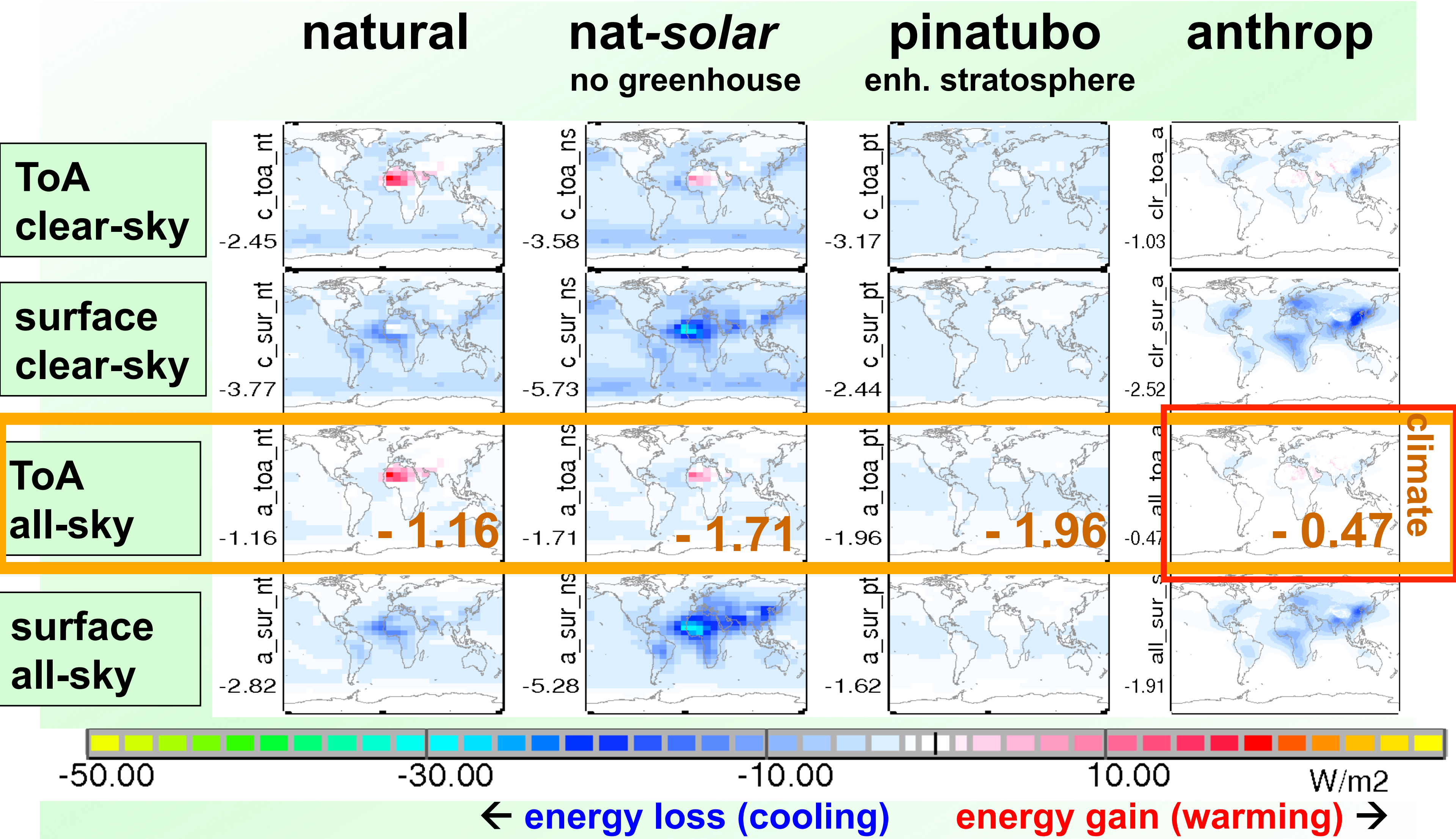
← energy loss (cooling) energy gain (warming) →

- clear solar impact is larger
  - over deserts (no greenh.)
  - over regions with clouds



natural vs. anthropogenic

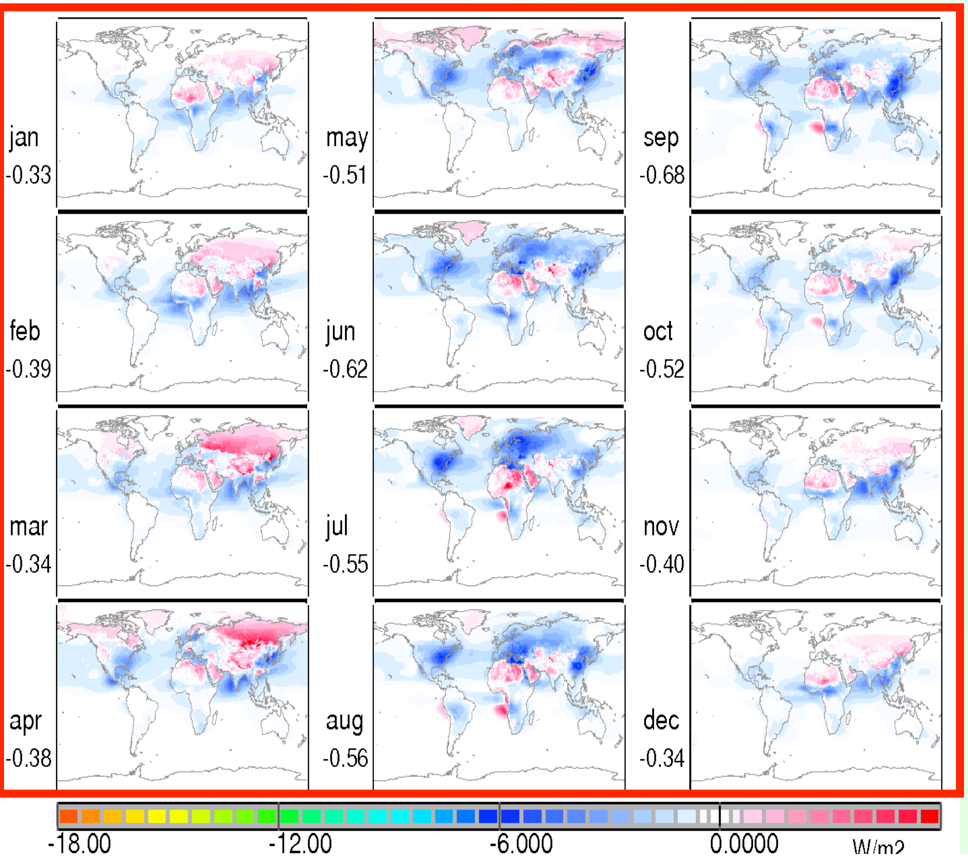
spatial pattern differs from anthropogenic



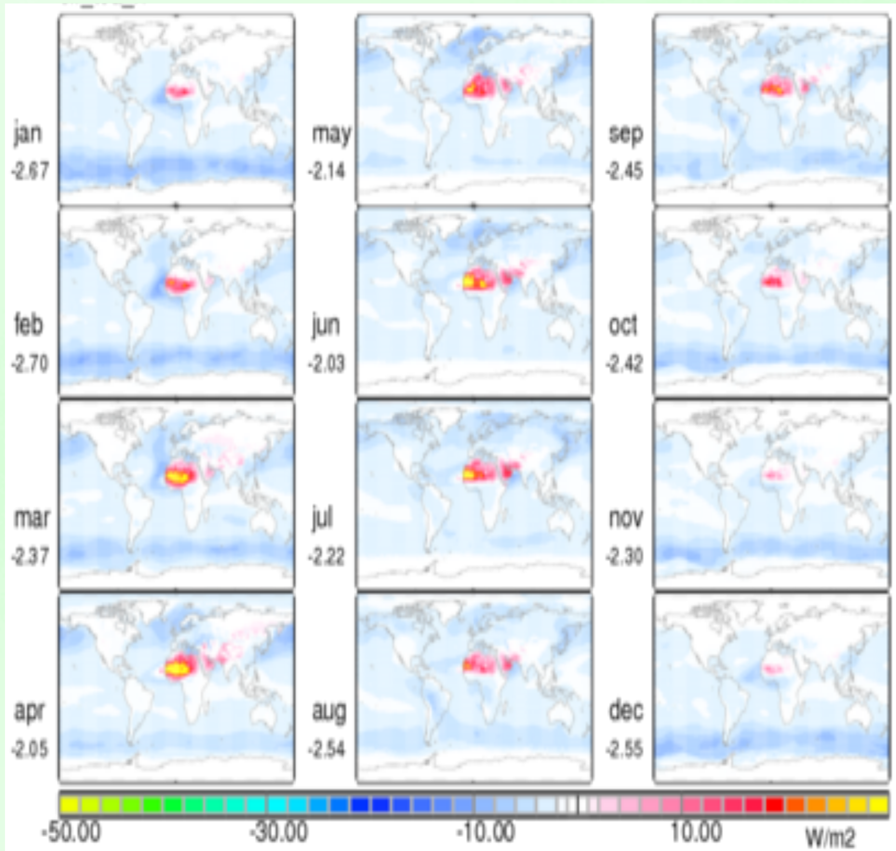
anthropogenic vs. natural - now

(different x-axis scales)

anthropogenic monthly



natural monthly



← cooling warming →

← cooling warming →

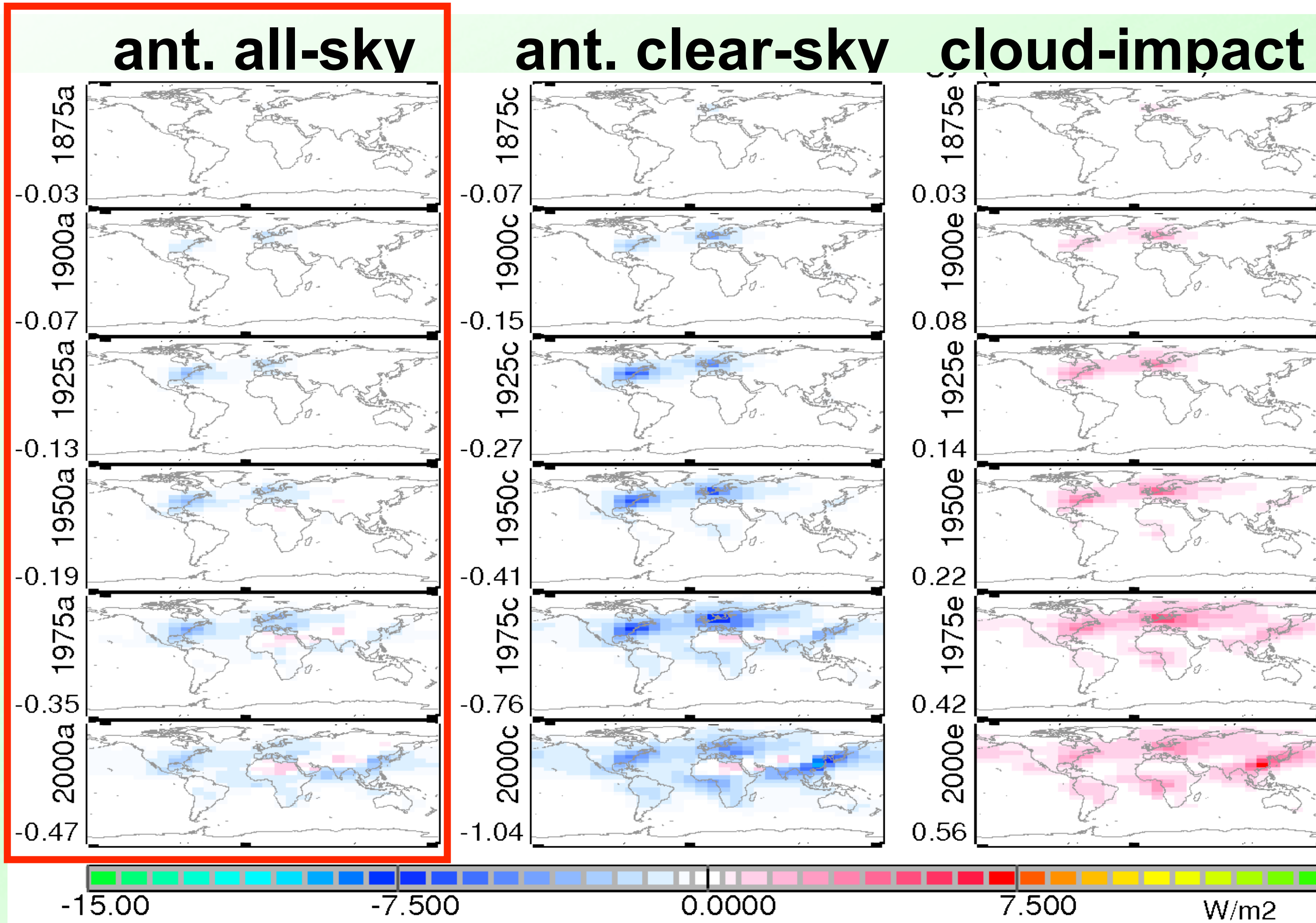
note … different scales !

patterns and strength vary strongly (dust warming over deserts)

past anthropogenic - ToA

increased most rapidly in the 1950-1990 period

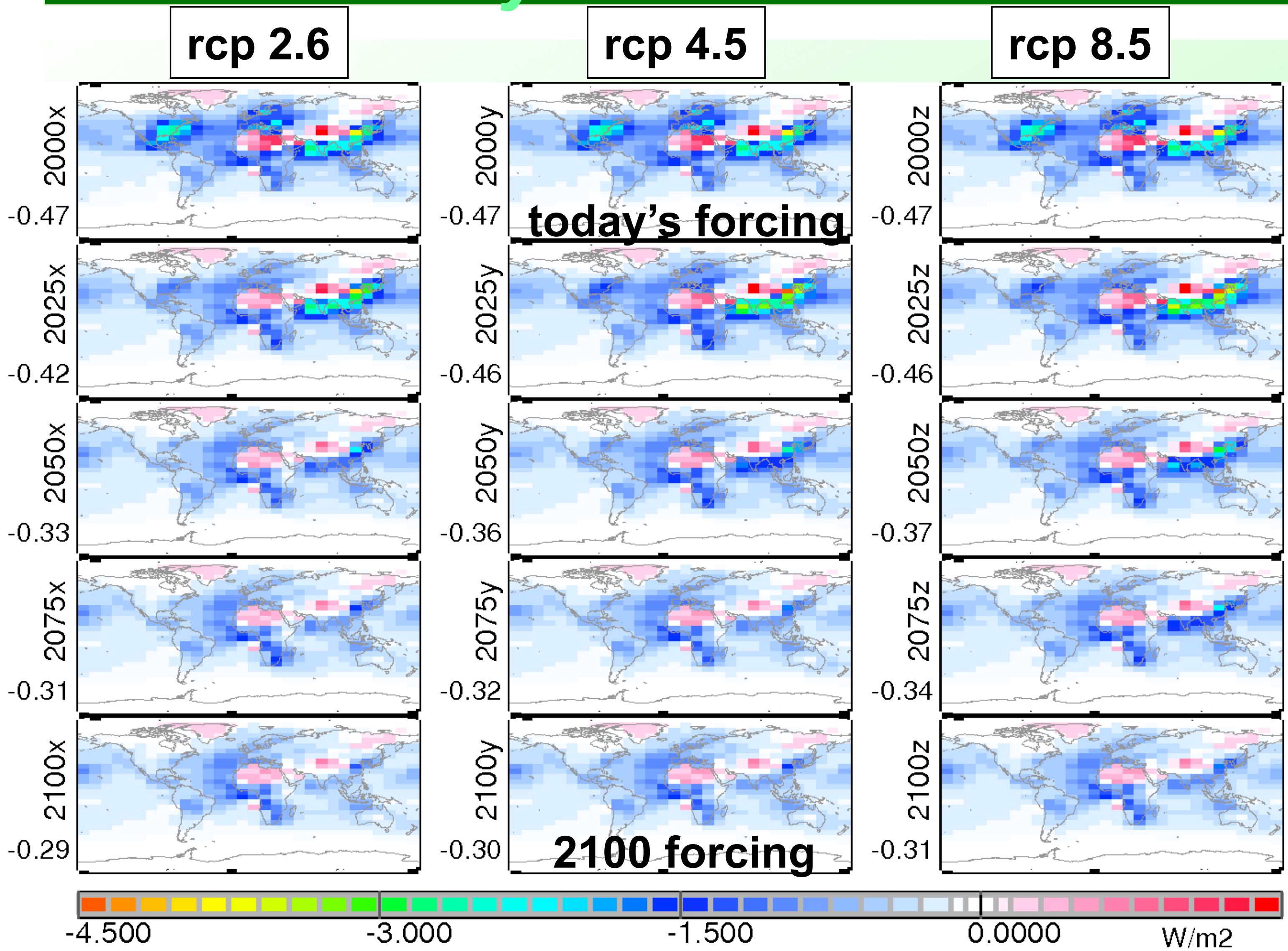
W/m2
1875: - 0.03
1900: - 0.07
1925: - 0.13
1950: - 0.19
1975: - 0.36
2000: - 0.47



← energy loss (cooling) energy gain (warming) →

future anthropogenic - ToA

will reduce by 2100 to about 65% of today's



	W/m2
2000	-0.47
2025	-0.46
2050	-0.37
2075	-0.34
2100	-0.31

anthropogenic forcing - summary

- today's forcing: - 0.5W/m2 at ToA, -1.9 at surface
  - usually small compared to natural aero forcing
    - 30% (only 15% with Pinatubo) at ToA
    - 40% (only 30% with Pinatubo) at surface
- strongest increase in the 1950 – 1990
- should hit its maximum by 2020
- should return to 1970 levels by 2100
- the different warming scenarios are similar
    - 2100 ToA rcp 2.6 - 0.29 W/m2
    - 2100 ToA rcp 4.5 - 0.30 W/m2
    - 2100 ToA rcp 6.5 - 0.31 W/m2

global vs east-Asia

global

anthrop aerosol forcing:

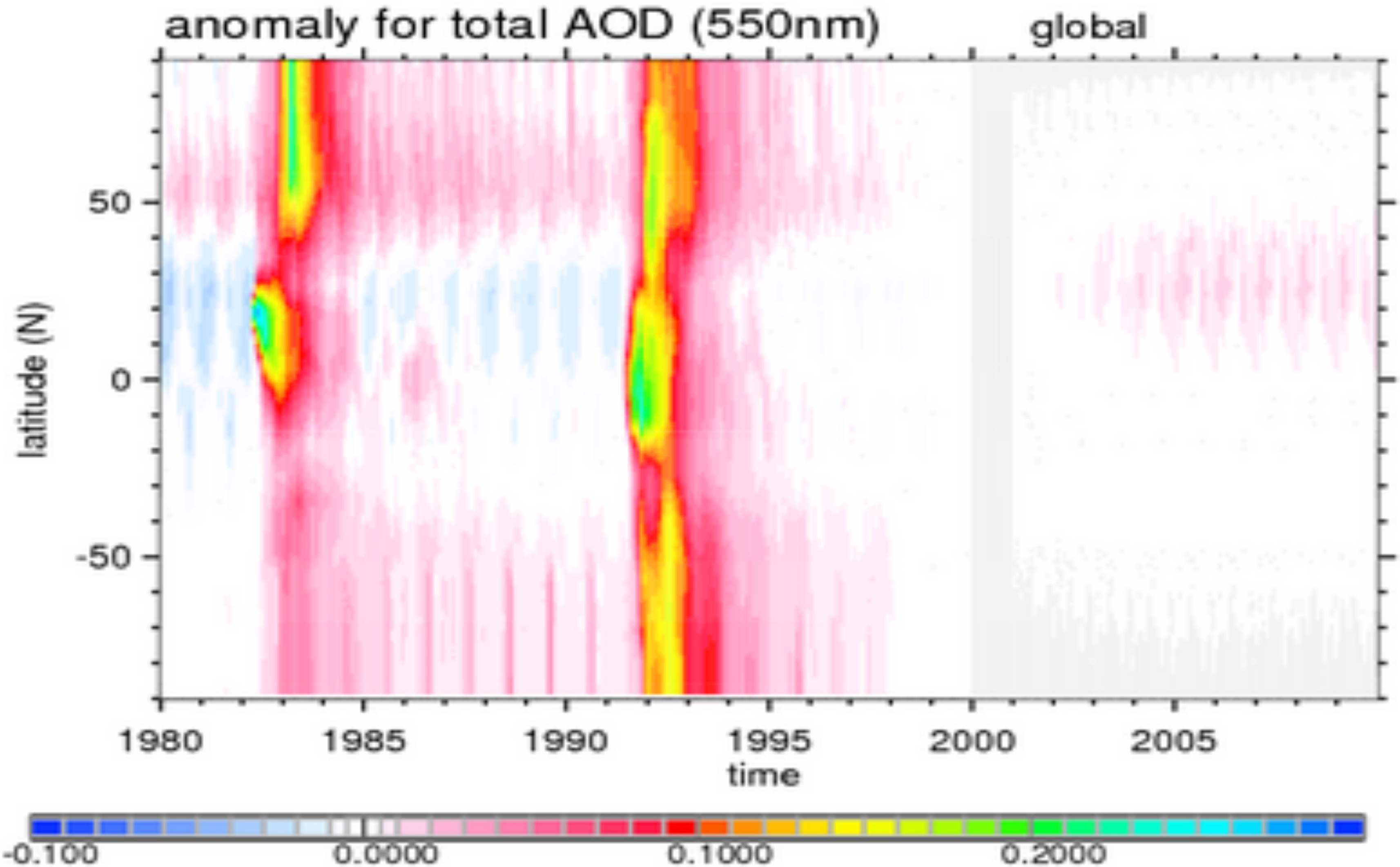
- ToA average -0.47 W/m2
- ToA season -.36 to -.68
- surf average -1.9 W/m2
- maximum expected 2020
- predictions for 2100
  - 35% less than today
  - near 1970 levels
  - scenarios are similar

eastern Asia

anthrop aerosol forcing:

- ToA average -1.23 W/m2
- ToA season -.2 to -2.2
- surf average -6.2 W/m2
- maximum expected 2030
- predictions for 2100
  - 55% less than today
  - near 1975 levels
  - scenarios are similar

looking for trends …



resource

data access ftp ftp-projects.zmaw.de

year 2000 properties

- cd aerocom/climatology/2010/yr2000
  - look at 'README_nc'

– ss-properties for the 14 solar-bands of ECHAM6

- g30_sol.nc total aerosol (yr 2000)
  - g30_coa.nc coarse mode aerosol
  - g30_pre.nc fine-mode pre-industrial (yr 1850)
  - g30_ant.nc fine-mode anthropogenic (yr 2000)

– ss-properties for the 16 IR-bands of ECHAM6

- g30_fir.nc total (=coarse mode) aerosol

– CCN and IN fields

- g_CCN_km20.nc for supersat. of 0.1, 0.2, 0.4 and 1%
  - anthrop. CCN is changing along with anthrop. AOD

data access ftp ftp-projects.zmaw.de

anthropogenic change

- **cd aerocom/climatology/2010/ant_historic**
  - **based on decadal change by ECHAM/HAM simulations for fine mode aerosol with NIES historic emissions**
    - **aeropt_kinne_550nm_fin_anthropAOD_yyyy.nc**
      - » simulations by Silvia Kloster, prep. by Declan O'Donnell

- **cd aerocom/climatology/2010/ant_future**
  - **based on sulfate and carbon emission related regional changes to fine-mode AOD patterns with ECHAM/HAM for IPCC *RCP 2.6*, *RCP 4.5* and *RCP 8.5* scenarios till 2100**
    - **aeropt_kinne_550nm_fin_anthropAOD_rcp??_yyyy.nc**
      - » simulations by Kai Zhang, concepts by Hauke and Bjorn

data access ftp ftp-projects.zmaw.de

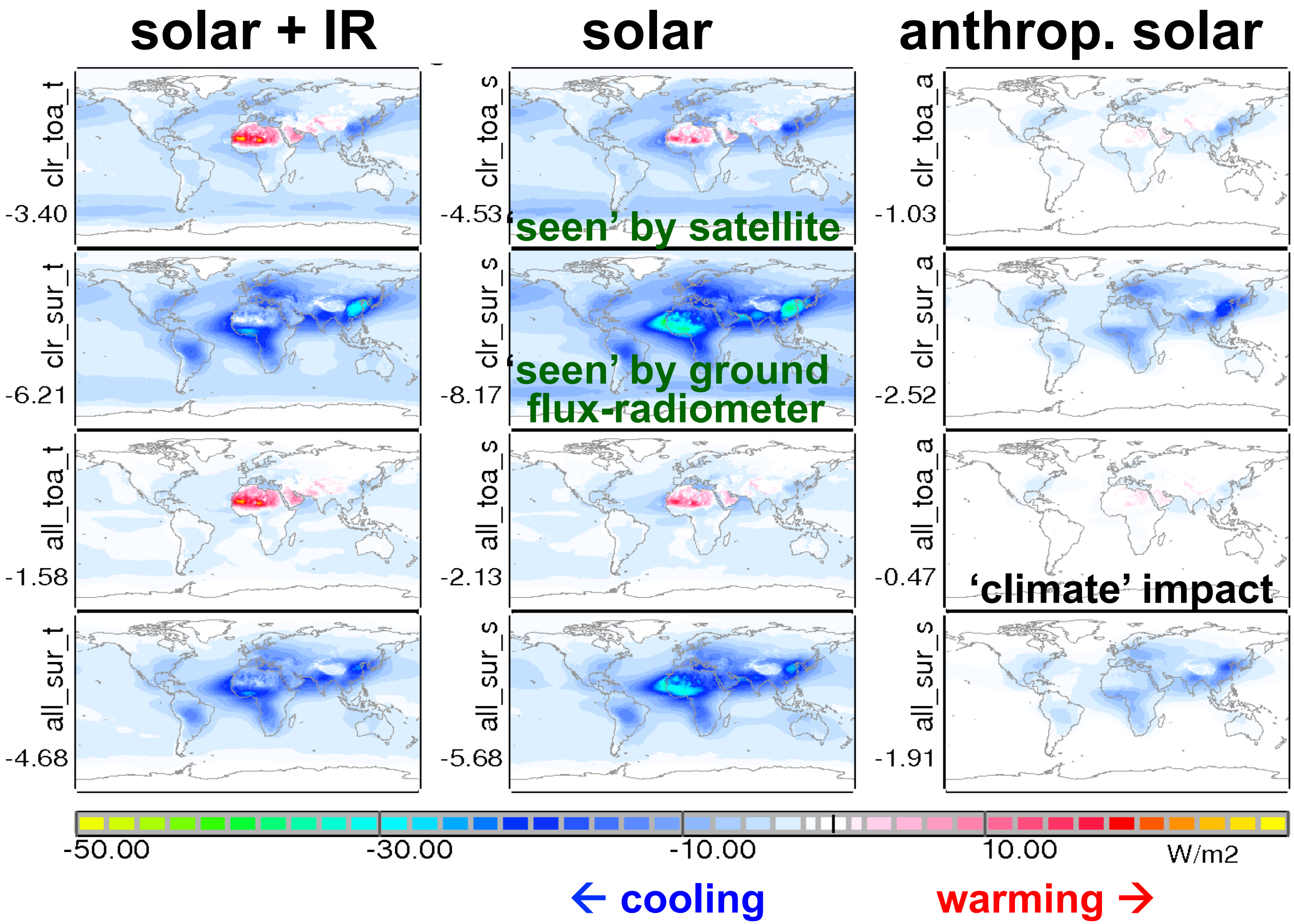
altitude

- cd aerocom/climatology/2010/altitude
  - based on CALIPSO version2 multi-annual data
  - fine/coarse mode altitude differences via ECHAM/HAM
    - calipso_fc.nc
      - » CALIPSO data via Dave Winker (NASA_LaRC)
      - » ECHAM/HAM altitude data from Philip Stier

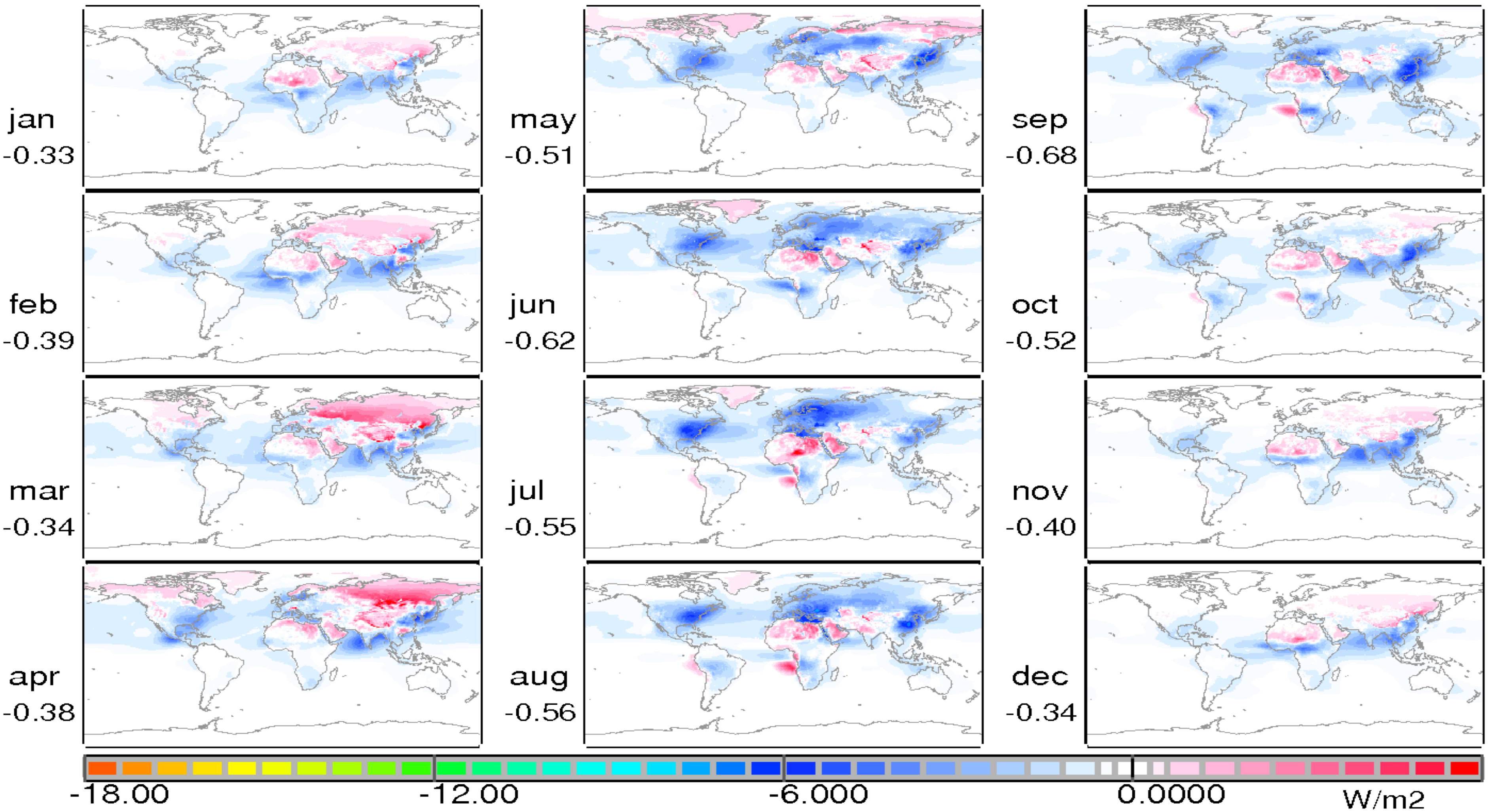
- cd aerocom/climatology/2010/ccn_historic
  - applying anthropogenic change to CCN concentrations
    - CCN_1km_yyyy.nc at 1km above ground
    - CCN_3km_yyyy.nc at 3km altitude
    - CCN_8km_yyyy.nc at 8km altitude

direct forcing/effects global patterns

- clear ToA
- clear surface
- all-sky ToA
- all-sky surface



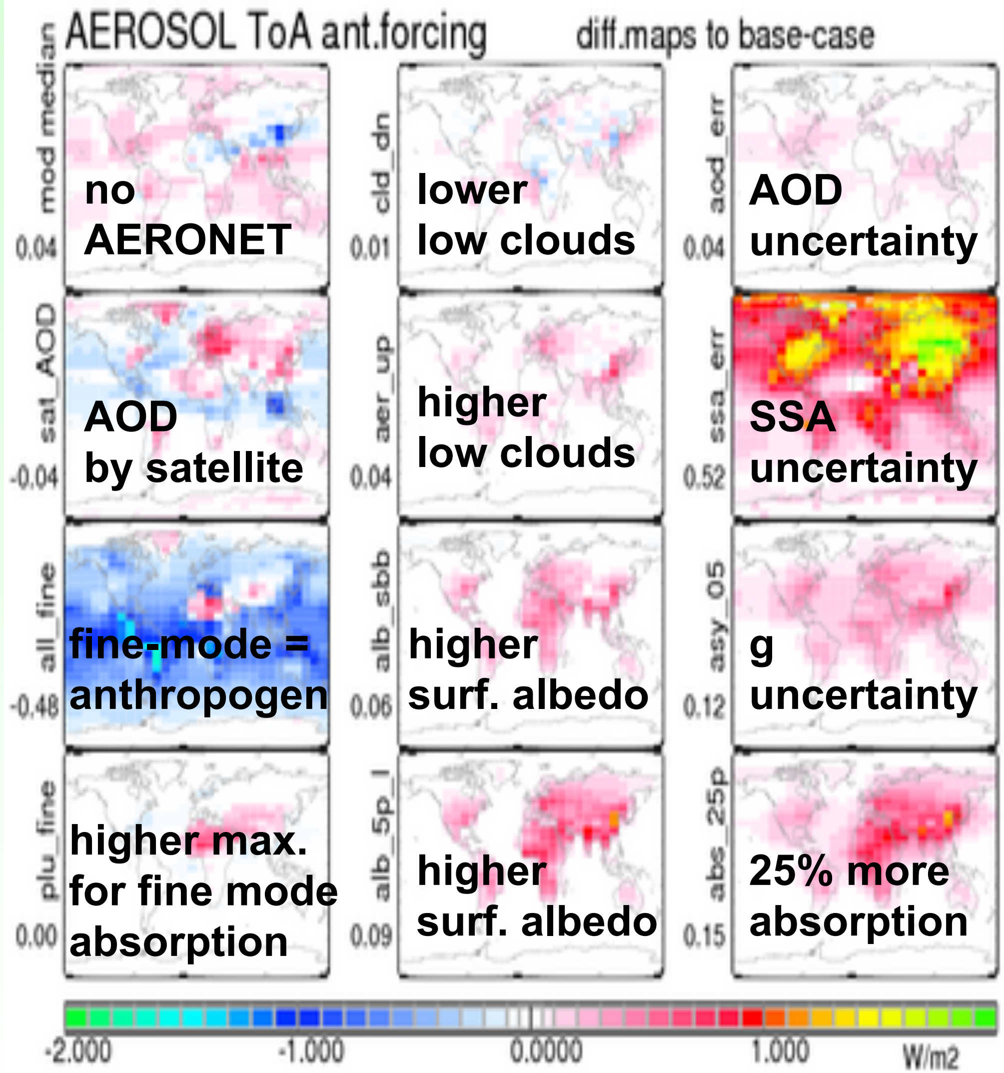
direct ToA forcing – seasonality



← cooling warming →

direct forcing - sensitivity tests

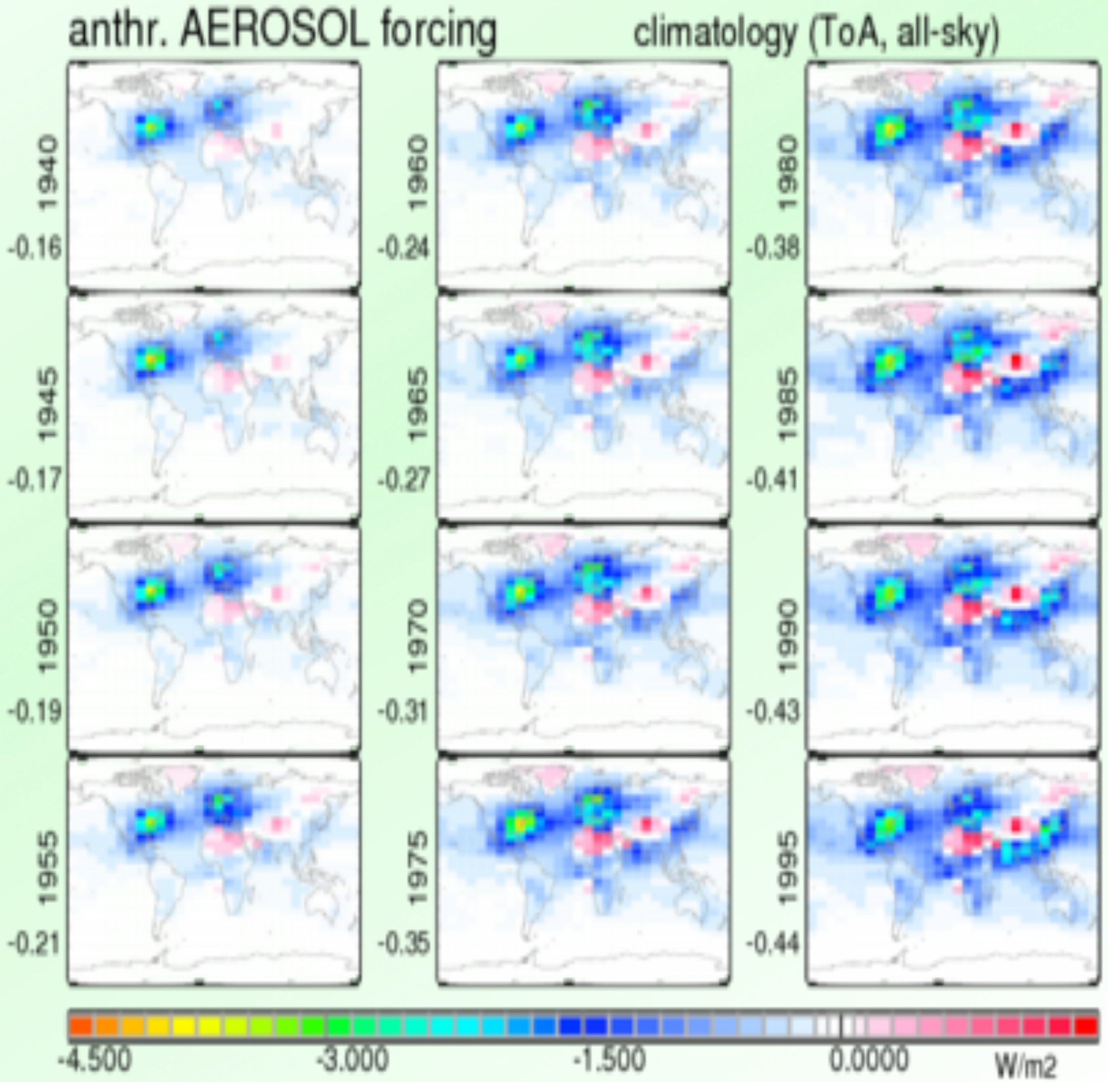
- ToA all-sky forcing uncertainty
  - examine impact by changing individual prop. to aerosol or environment
    - +/- 0.3 W/m2



anthrop. direct forcing in time

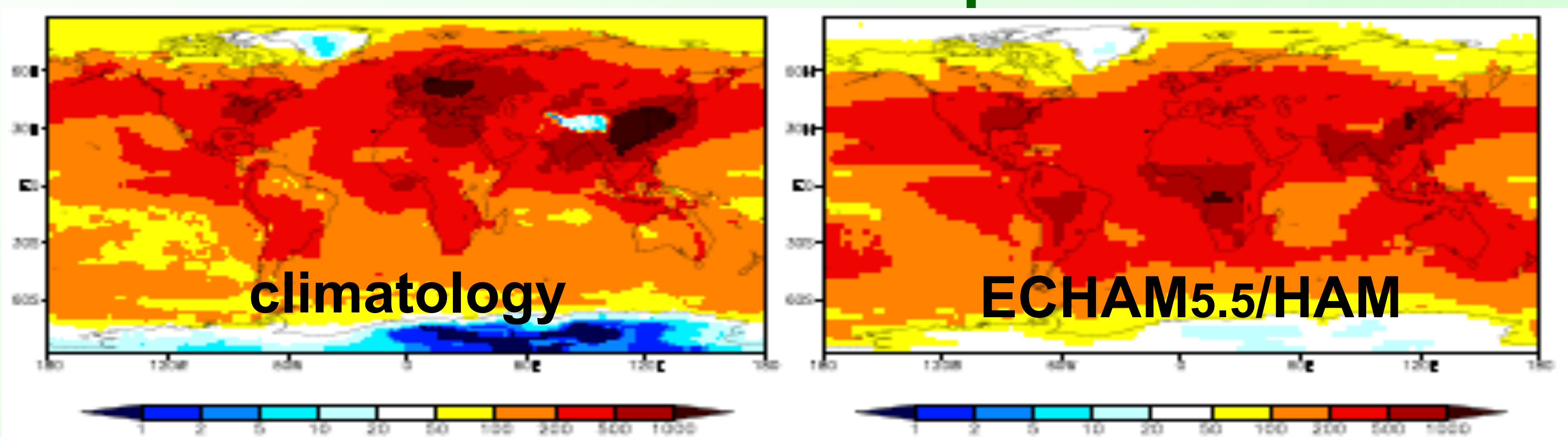
- **changing pattern**
  - 1940: -.16 W/m^2
  - 1945: -.17 W/m^2
  - 1950: -.19 W/m^2
  - 1955: -.21 W/m^2
  - 1960: -.24 W/m^2
  - 1965: -.27 W/m^2
  - 1970: -.31 W/m^2
  - 1975: -.35 W/m^2
  - 1980: -.38 W/m^2
  - 1985: -.41 W/m^2
  - 1990: -.43 W/m^2
  - 1995: -.44 W/m^2

strongest increase

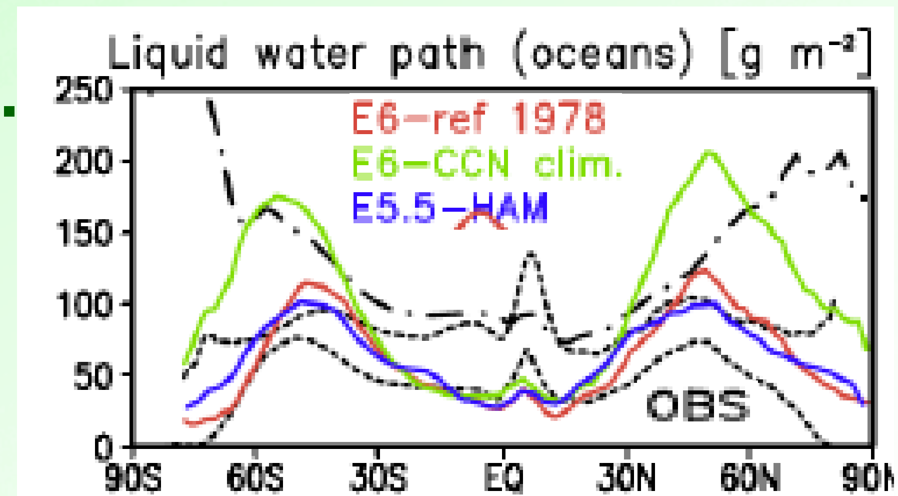


CCN – climatology in use

- **CCN /ccm3   at 1km 0.1% super-saturation**



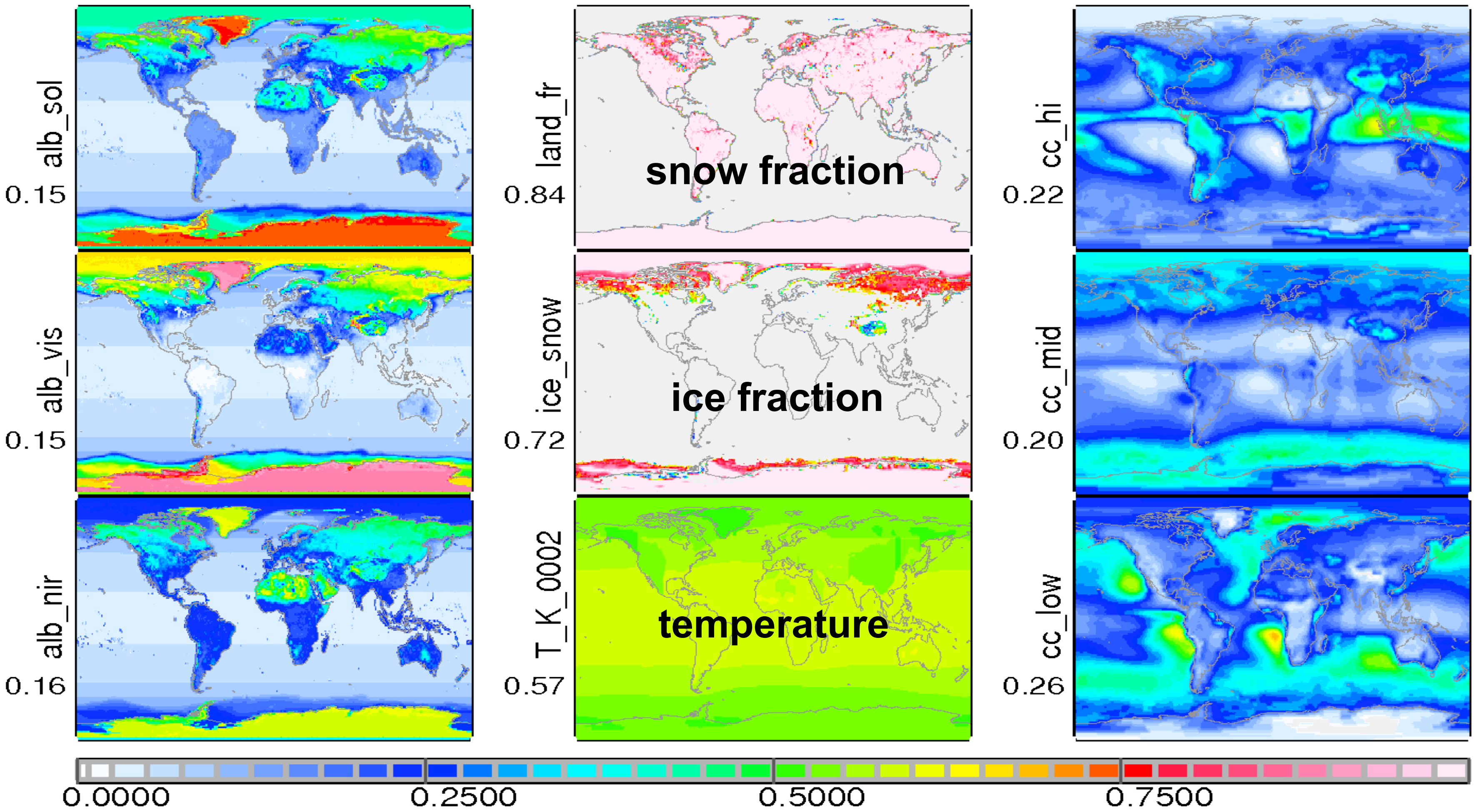
- **liquid water path comp.**
  - **stronger aerosol indirect effect with the climatology**



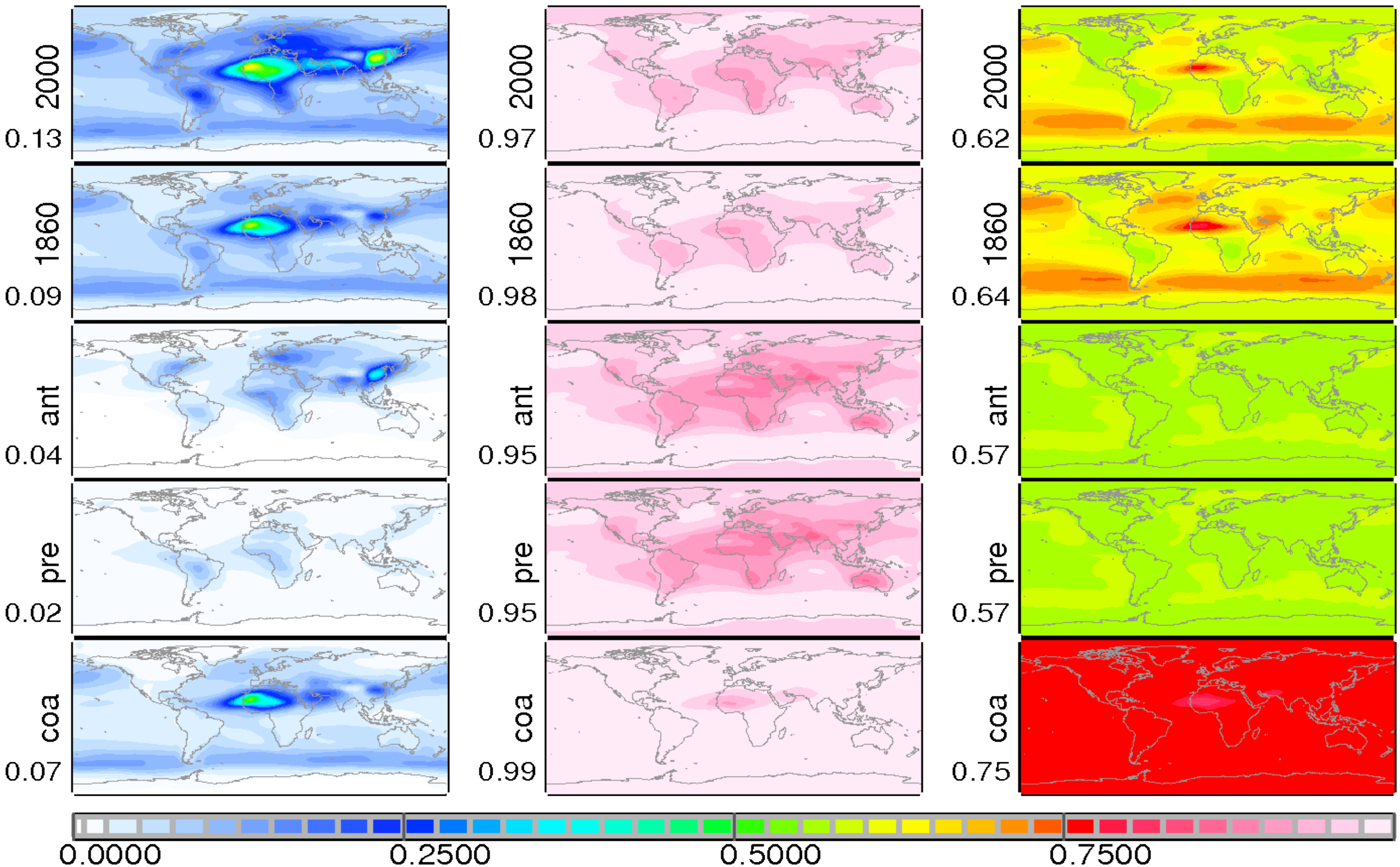
by U.Lohmann ETHZ

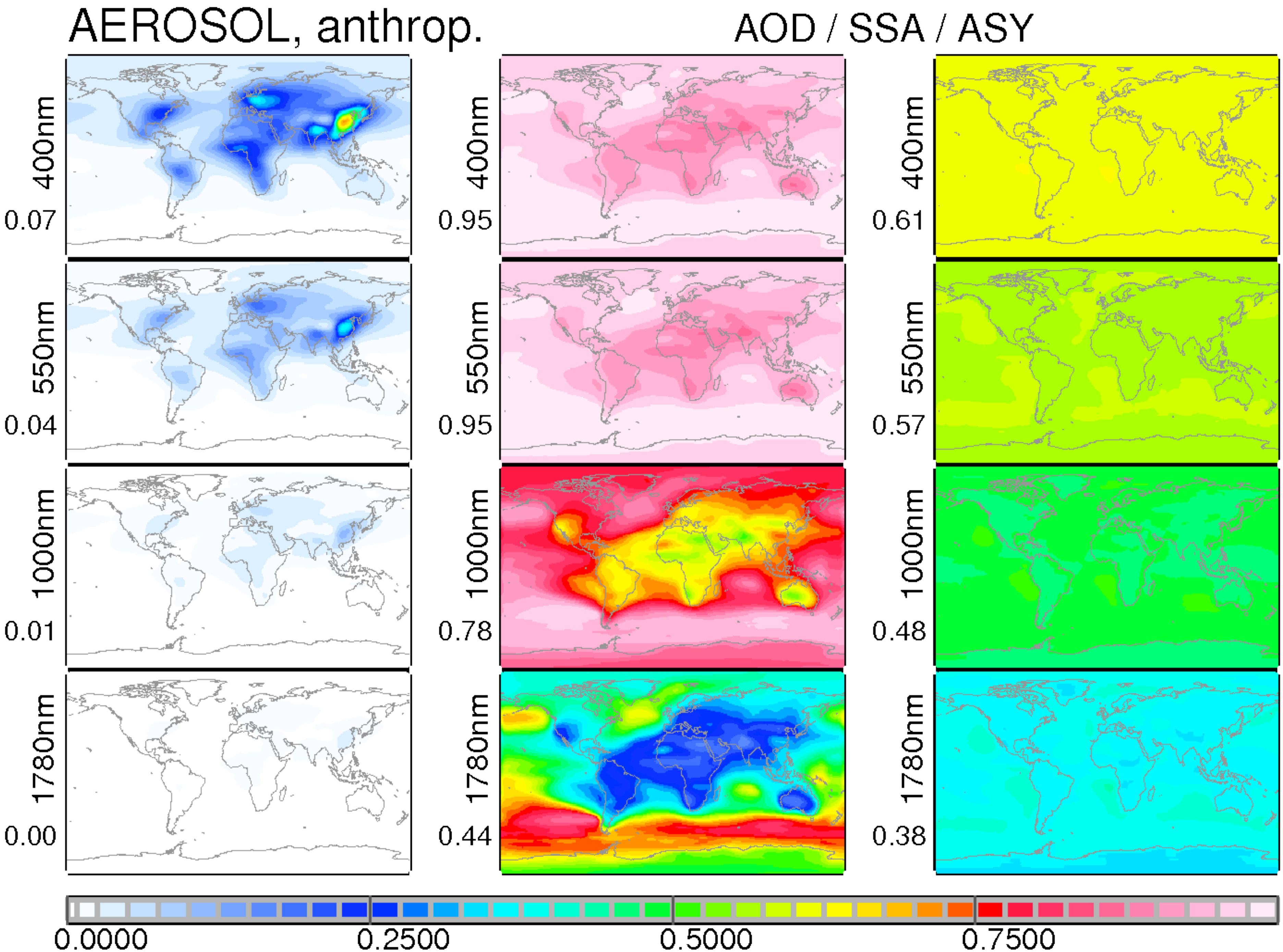
environmental data

albedo ***(MODIS + ice, snow)*** **clouds** ***(ISCCP)***

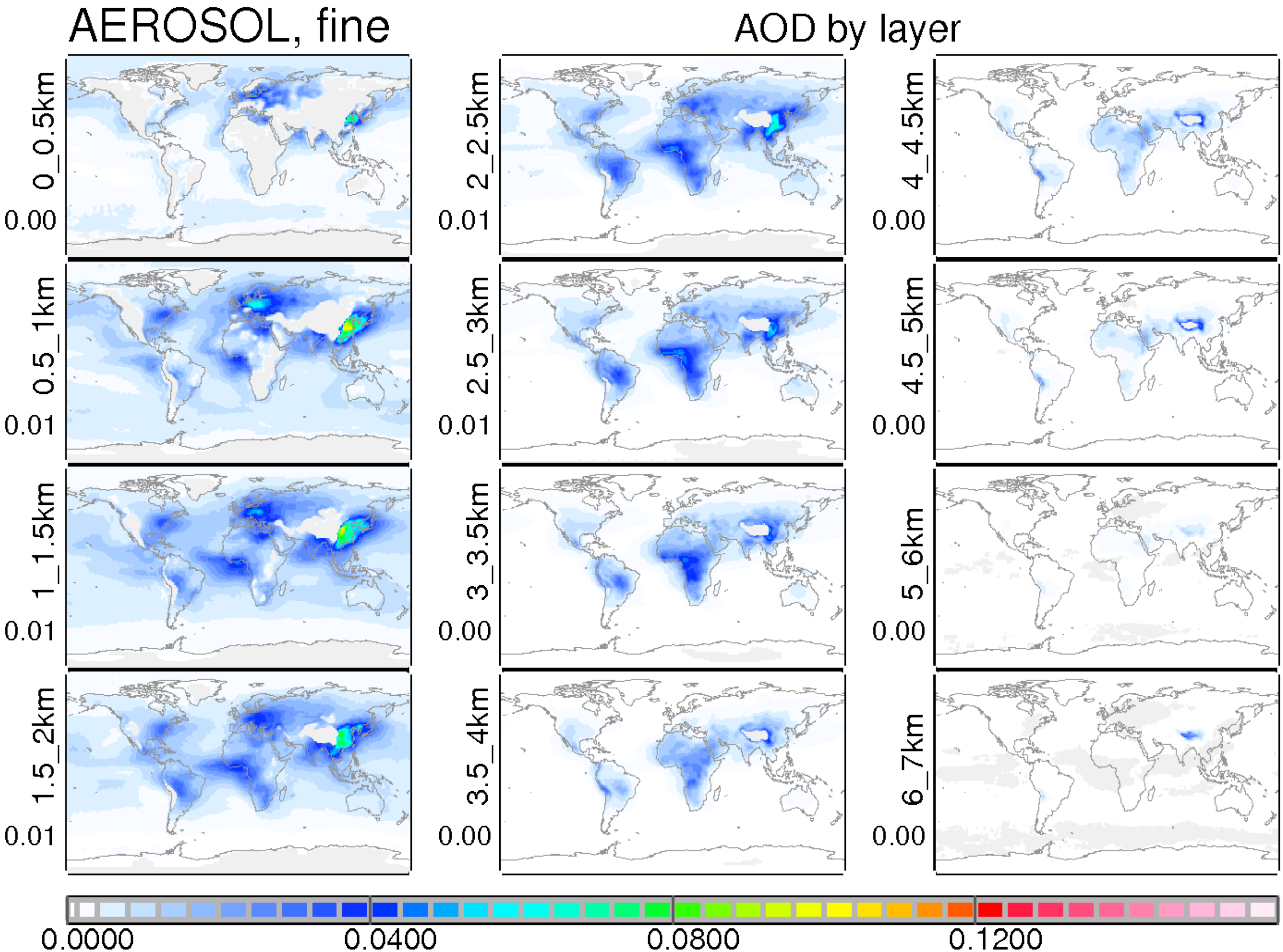


AOD / SSA / ASY at 550nm

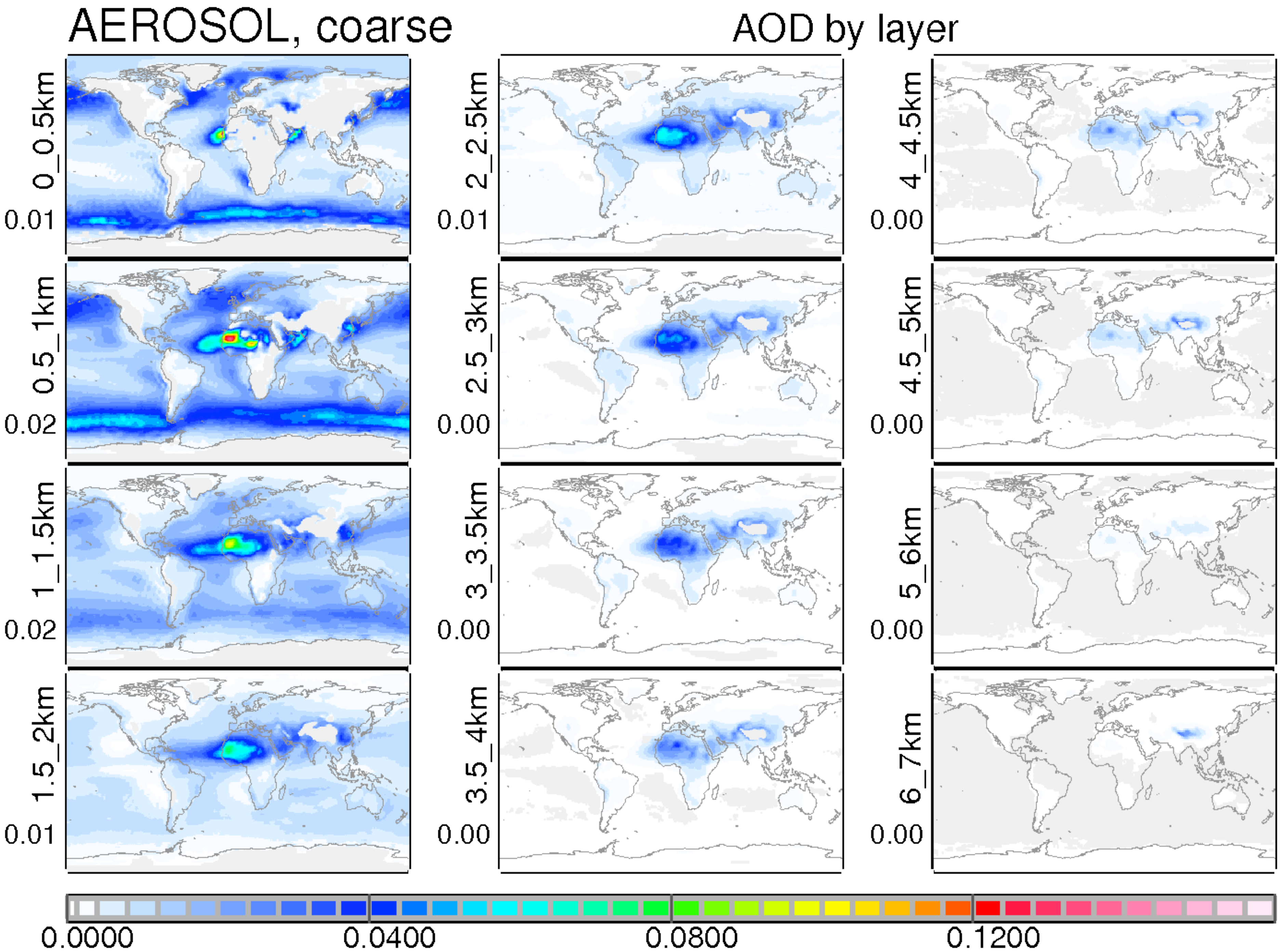




AEROSOL, anthrop.
AOD / SSA / ASY
400nm
0.07
550nm
0.04
1000nm
0.01
1780nm
0.00
400nm
0.95
550nm
0.95
1000nm
0.78
1780nm
0.44
400nm
0.61
550nm
0.57
1000nm
0.48
1780nm
0.38
0.0000
0.2500
0.5000
0.7500



AEROSOL, fine
AOD by layer
0_0.5km
0.00
0.5_1km
0.01
1_1.5km
0.01
1.5_2km
0.01
2_2.5km
0.01
2.5_3km
0.01
3_3.5km
0.00
3.5_4km
0.00
4_4.5km
0.00
4.5_5km
0.00
5_6km
0.00
6_7km
0.00
0.0000
0.0400
0.0800
0.1200



AEROSOL, coarse
AOD by layer
0_0.5km
0.01
2_2.5km
0.01
4_4.5km
0.00
0.5_1km
0.02
2.5_3km
0.00
4.5_5km
0.00
1_1.5km
0.02
3_3.5km
0.00
5_6km
0.00
1.5_2km
0.01
3.5_4km
0.00
6_7km
0.00
0.0000
0.0400
0.0800
0.1200