

aerosol radiative effects

with MACv2

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MPI-Meteorology



overview

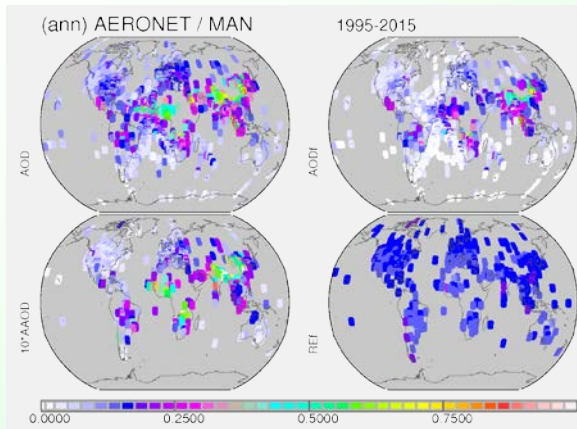
- **MAC defines 550nm optical properties globally**
- **via components → spectral info for rad. transfer**
- **direct radiative effects (total & components)**
- **anthropogenic direct impacts**
- **direct forcing efficiencies (total & components)**
- **anthropogenic indirect (low) cloud effects**
- **direct vs indirect anthropogenic effects**
- **TOA forcing over time**
- **temporal forcing change for dim-/bright-ening**

things to remember

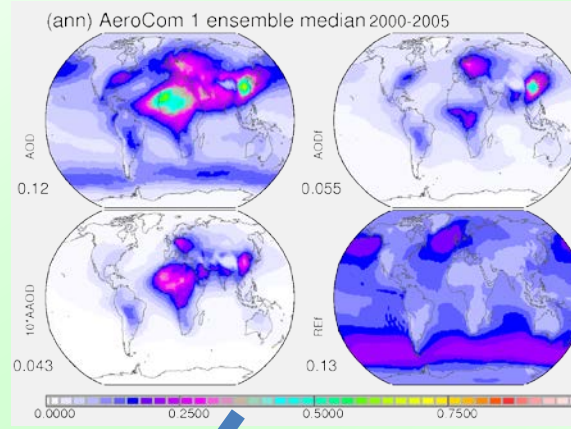
- **today's global forcing is at a global maximum**
- **forcing strength depends on 'anthropogenic' definition – especially for the indirect effect**
- **indirect forcing dominates at TOA ... and was early-on relative stronger than direct forcing**
- **atmospheric forcing (sol heat) is a direct effect**
- **direct forcing dominates at the surface**
- **there is significant spatial and temporal inhomogeneity for all aerosol radiative effects**

MACv2 ingredients

AERONET quality



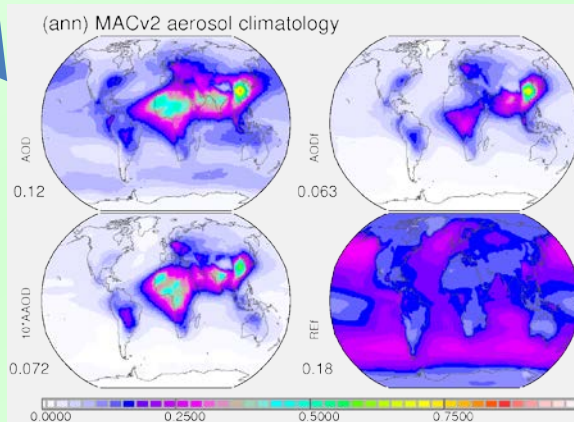
AEROCOM model spatial context



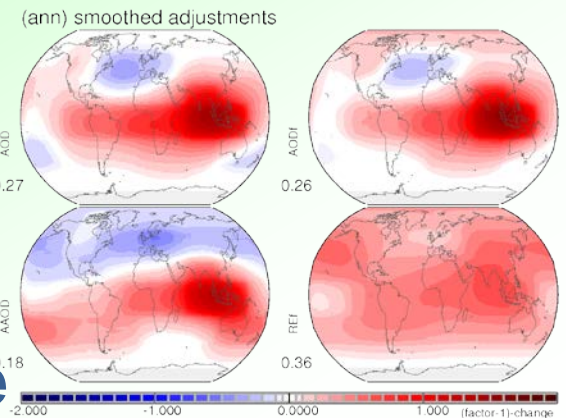
AOD | AODf

AAOD | REF

MACv2



changes
to model
increase
decrease



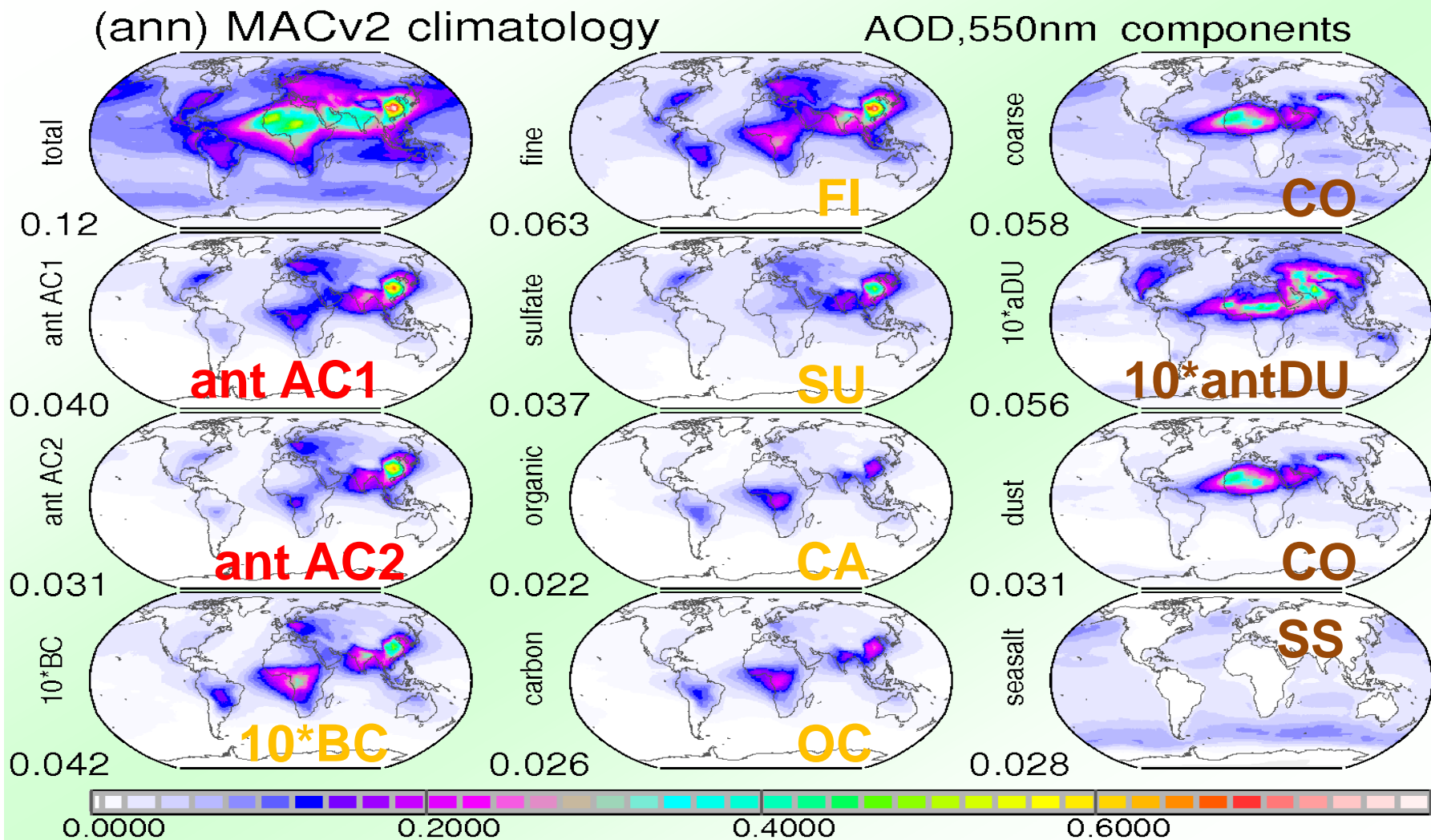
AOD_f, AOD_c, AAOD_f, AAOD_c, RE_f → component choices

- fine mode AOD 550nm
 - SU, OC or BC
 - fine mode AAOD 550nm
 - strong abs → BC (+OC shell) re = 0.12 μm
 - weak abs → OC [OC > 5*BC] re = 0.12 μm
 - non abs → SU re = 0.06 to 0.5 μm (← RE_f)
- coarse mode AOD 550nm
 - DU or SS
 - coarse mode AAOD 550nm
 - weak absorption → smaller & less dust
 - larger absorption → larger & more dust
 - no absorption → SS (SS, AOD_{min} over ocean req)

main points

- all components are 'radiatively' defined
 - even at not mid-visible wavelengths
- the mix of components is consistent with MAC
 - their sum reproduces AOD, AODc, AODf, AAOD, AAODf, AAODc and RE_{,fine} of MACv2
- In terms of global annual AOD (at 550nm)
 - SU: 0.037, OC: 0.022, BC: 0.04 total
 - DU: 0.031, SS: 0.028 0.122
 - with scaling via global modeling ...
 - anthrop: 0.030-0.041 (fine) 0.04-0.06 (coarse)

AOD assignments



the radiative transfer

- **2 stream method**
 - 20 bands (8 solar / 12 IR) 9 sun-elevations
 - random H/M/L cover overlap (8 permutations)
- **aerosol input**
 - MACv2: total & anthro (time, SU,BC,OC,SS,DU)
 - modeling: altitude-distr & fine anthro fraction
- **environment**
 - ISCCP: clouds (H/M/L) Cs,C1,C5 microphysics
 - MODIS: land VIS n-IR surface albedo
 - US std atmos: atmospheric profiles

direct effects – annual averages

in W/m²

clear-sky

all-sky

- at TOA

• today total solar+IR	-2.3	-1.1
• today total solar	-3.5	-1.8
• today anthropogenic	-0.7	-0.36

- at surface

• today total solar+IR	-4.6	-4.0
• today total solar	-7.4	-5.5
• today anthropogenic	-1.9	-1.5

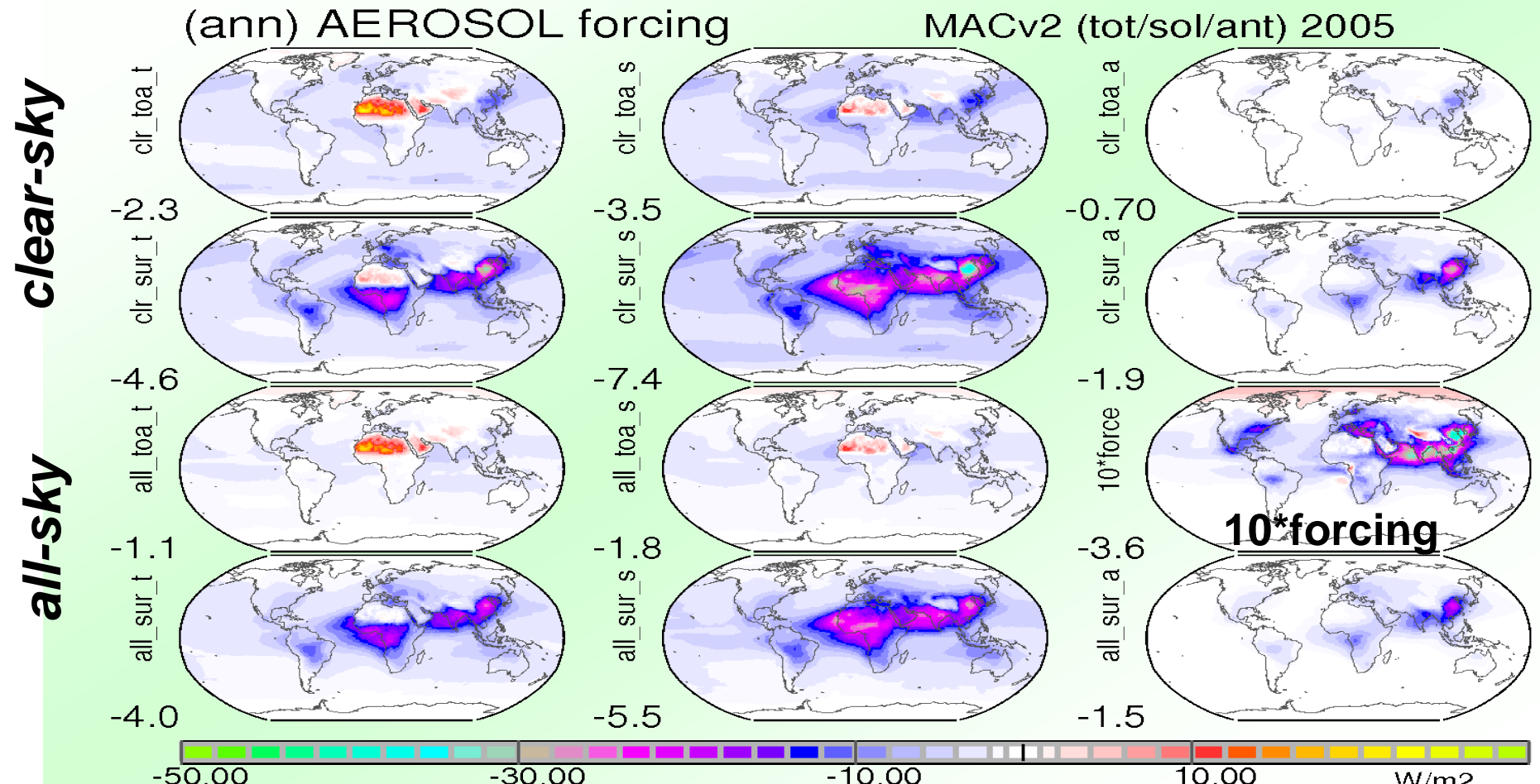
- for atmosphere

• today total solar+IR	2.3	2.9
• today total solar	3.9	3.7
• today anthropogenic	1.2	1.1

today's direct effects

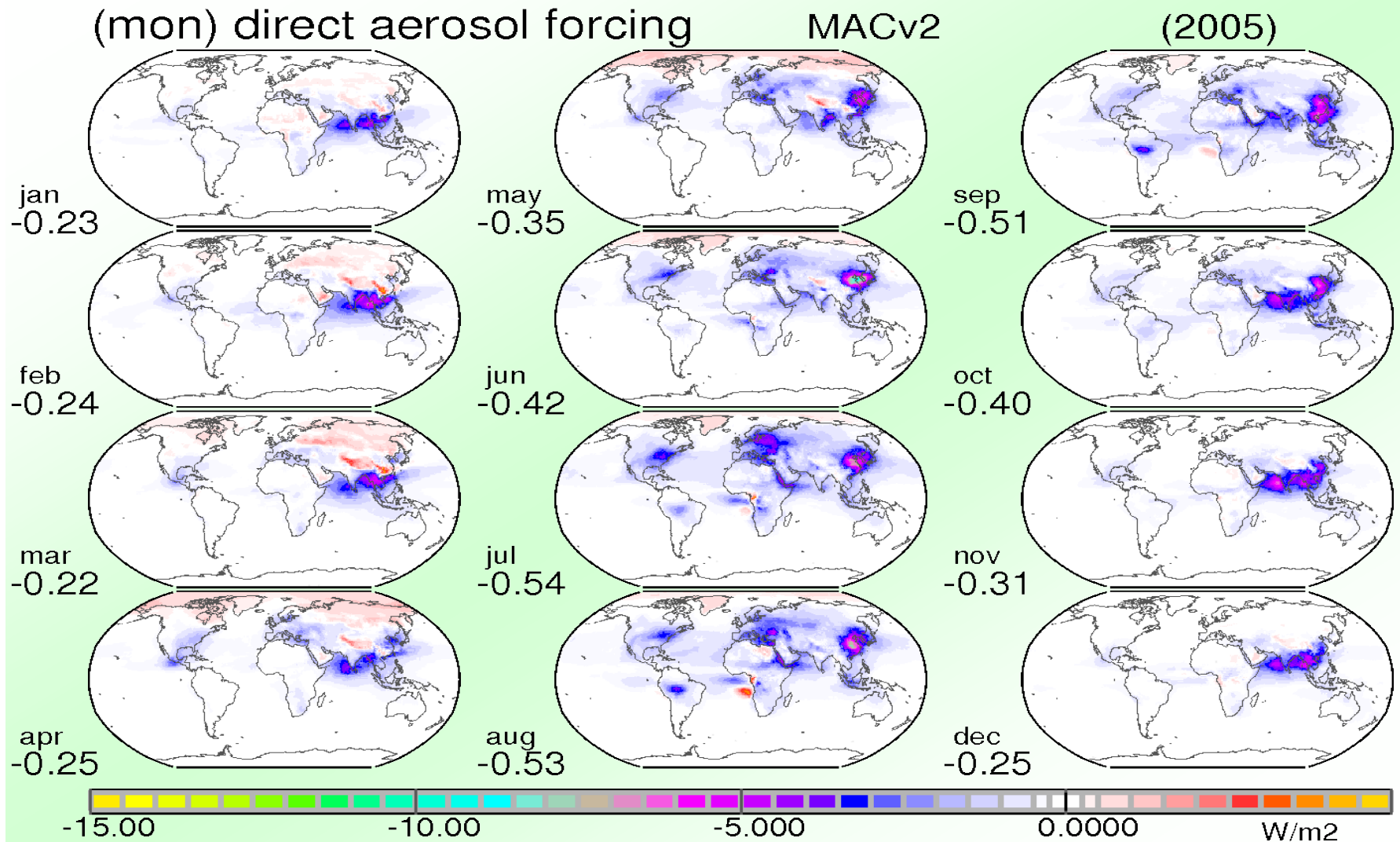
cooling and warming

- total (solar+IR) / total (solar) / anthropogenic



today's direct forcing - 0.35 W/m²

monthly variations



direct component forcing

today

in W/m²

clear-sky

all-sky

- at TOA

• Total	-2.3	-1.1
• Dust (DU)	-0.29	+0.25
• Seasalt (SS)	-0.94	-0.55
• Organic (OC)	-0.68	-0.45
• Sulfate (SU)	-1.1	-0.80
• Soot (BC)	+0.46	+0.55
– anthropogenic		
• Dust (DU) (Ginoux)	-0.02	0.02
• Organic (OC)	-0.33	-0.22
• Sulfate (SU)	-0.58	-0.40
• Soot (BC)	+0.24	+0.28
• anthrop Soot (BC)	+0.37	+0.44

forcing efficiency /AOD

lots of spatial variability

- **at TOA** *(influenced by aerosol and albedo)*
 - **total and anthropogenic averages are similar**
 - **at clear-sky :** - 22 W/m² / AOD
 - **at all-sky:** - 11 W/m² /AOD
 - **by component**
 - **SS: -18 / DU: -5 / SU: -21 / OC: -19 / BC: -150**
CA (OC+BC): +8
- **at surface** *(influenced by aerosol)*
 - **total (-solar) and anthr. averages are similar**
 - **at clear-sky:** - 56 W/m² /AOD
 - **at all-sky:** - 40 W/m² /AOD

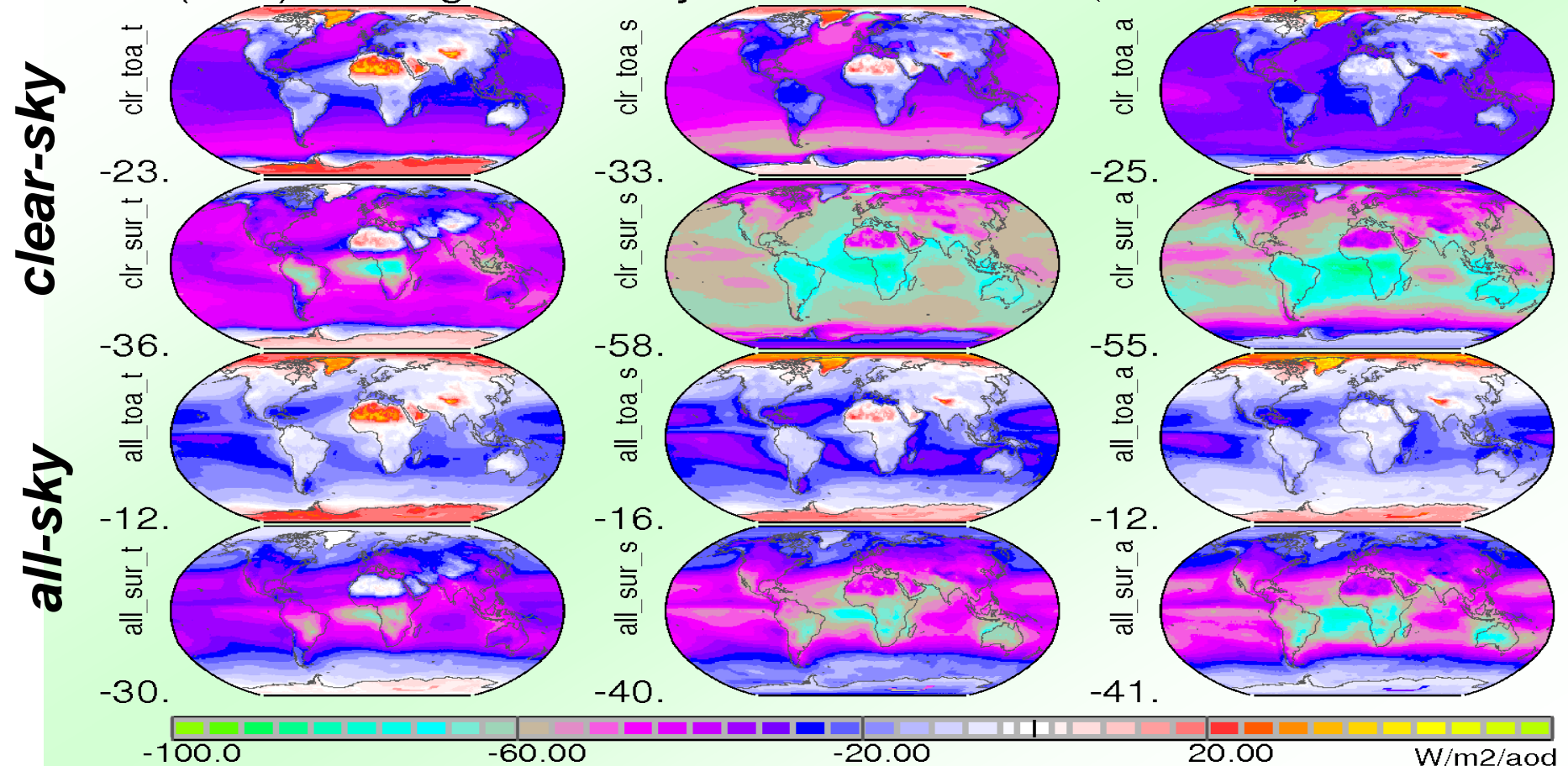
direct forcing efficiency / per AOD

more more cooling and warming

- total (solar+IR) / total (solar) / anthropogenic

(ann) forcing efficiency

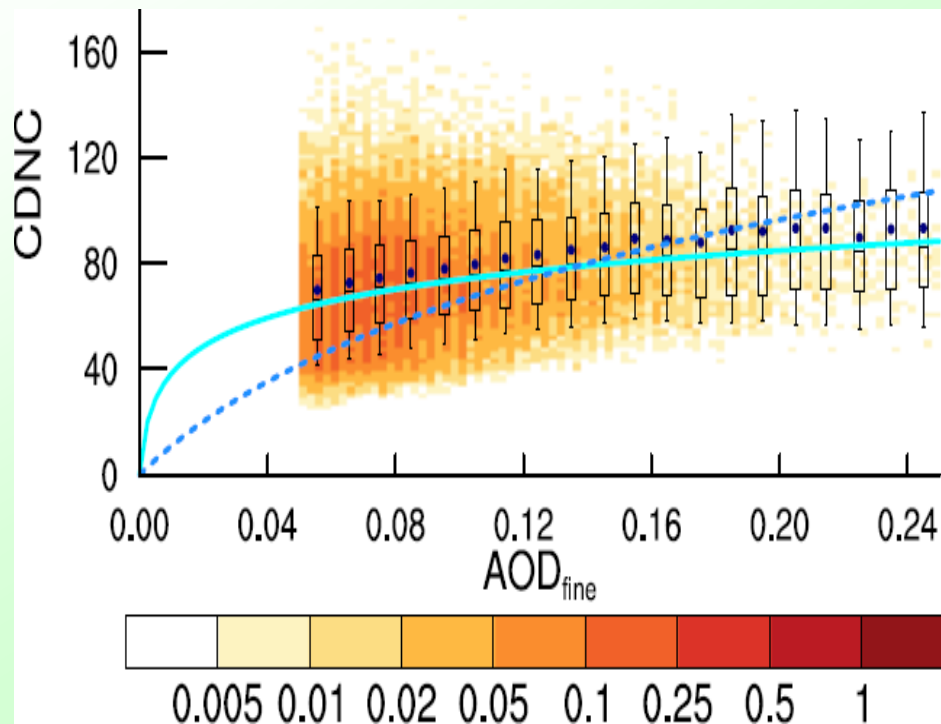
MACv2 (tot/sol/ant) 2005



indirect effects

relate aerosol number to more drops (/smaller R)

- **CDNC, factor** = $\frac{\ln(1000 \cdot \text{AOD}_f [\text{nat} + \text{anthr}] + 3)}{\ln(1000 \cdot \text{AOD}_f [\text{natural}] + 3)}$
increase



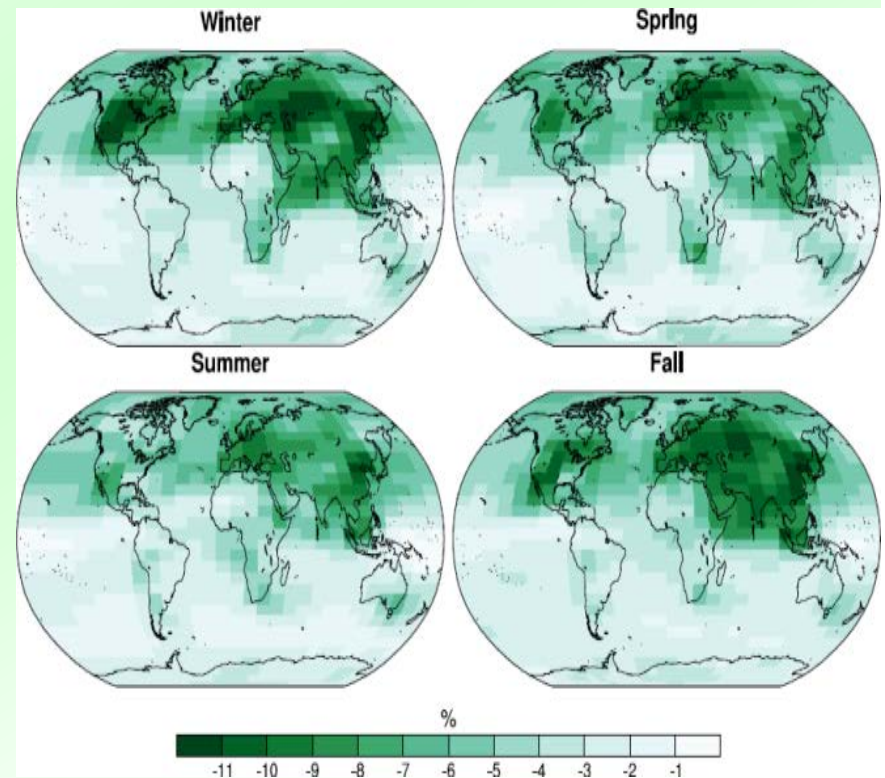
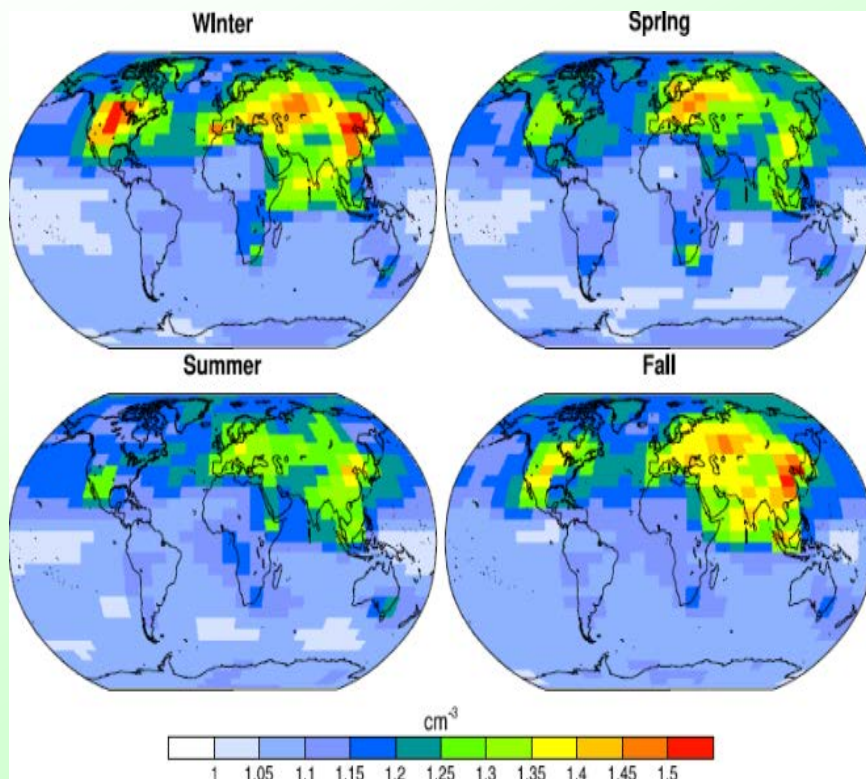
... based on satellite based 'observations' (MODIS and ATSR data are consistent

modeling on average displays a stronger relationship

impact on low clouds

seasonal change by today's anthrop aerosol

- increase factor to droplet (CDNC) *left*
- % drop radius reduction (LWC constant) *right*

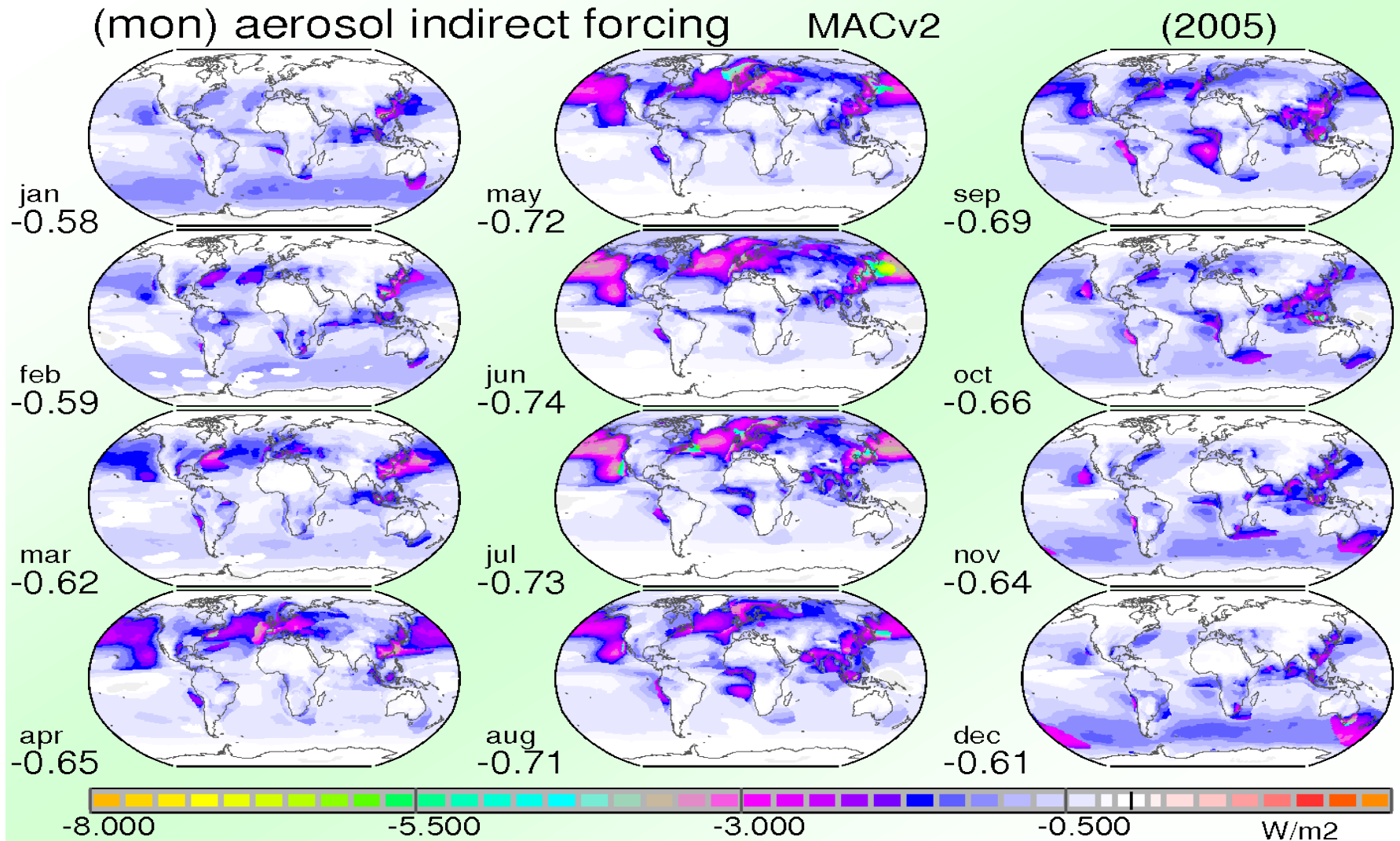


indirect effect

- aerosol indirect effects are just approximated by the 1. indirect effect (*Twomey*) to water clouds
 - cloud life-time aerosol induced changes are smaller (e.g. Malavelle - Island Volcano Study) also as potential evaporation and delayed precip effects partially offset each other.
- water cloud droplets were reduced in the model
 - reduced planetary (solar) albedo (*a cooling*)
 - other influences than cloud microphysics are
 - available sunlight
 - low clouds with non clouds on top
 - dark backgrounds (ocean)
 - clouds with med opt depth (susceptibility)

indirect TOA forcing - 0.66 W/m²

monthly variations



today's indirect mainly solar effect

strong anthropogenic (fine fraction) influence

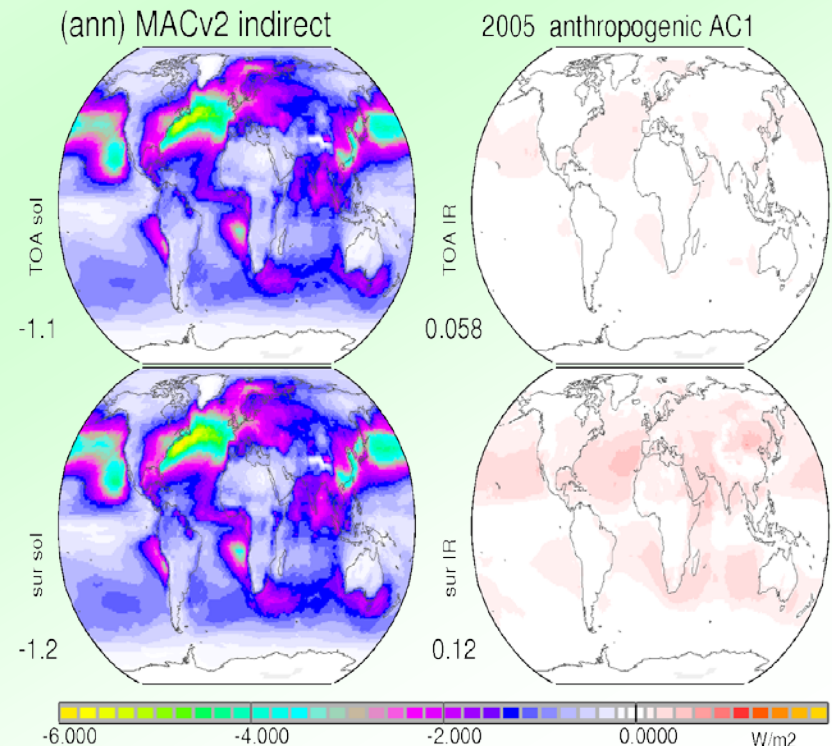
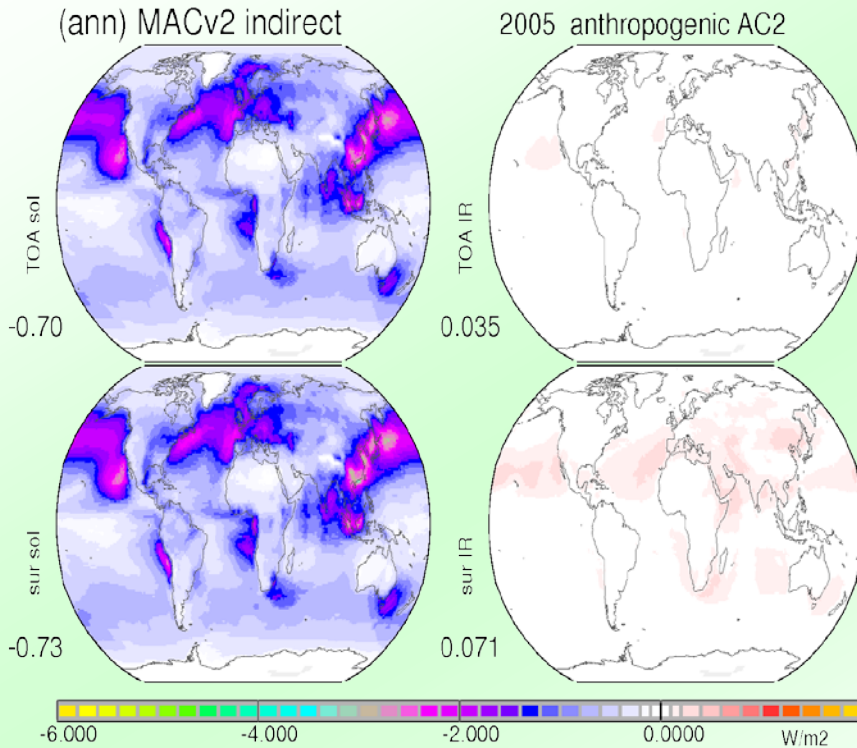
• **AeroCom2 ant**
Lamarque

TOA sol / TOA IR
surf sol / surf IR

AeroCom1 ant
Dentener

- 0.66 W/m²

- 1.05 W/m²



direct vs indirect

- **comparisons of today's direct and indirect anthropogenic aerosol effects**
 - **direct effects are more variable - both signs**
 - **indirect effects (by definition) are all negative**
 - **indirect effects are 2:1 dominant at TOA**
 - **only direct effects loose heat to atmosphere**
 - **thus.. direct effects are 2:1 dominant at surface**
 - **direct effects are stronger near sources**
- **'clear-sky direct' to approximate 'total' effects?**

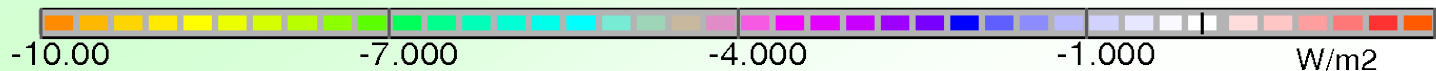
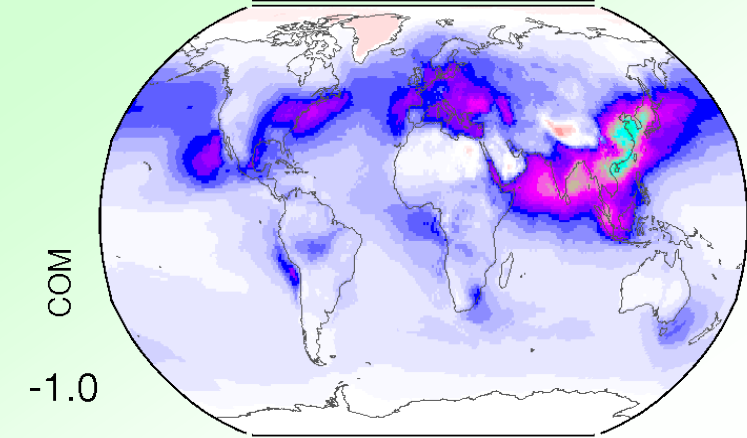
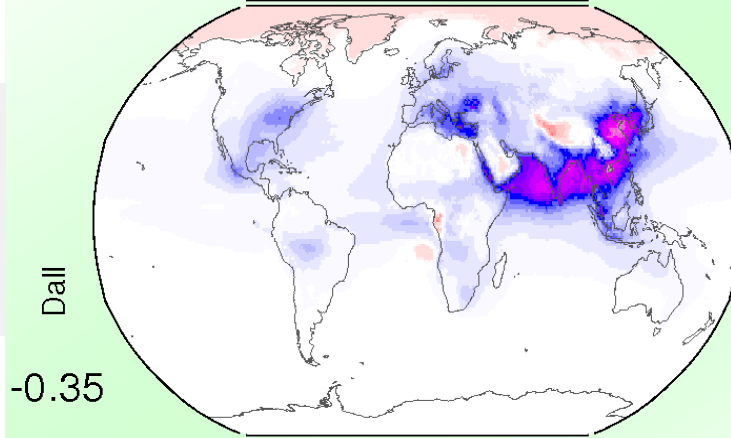
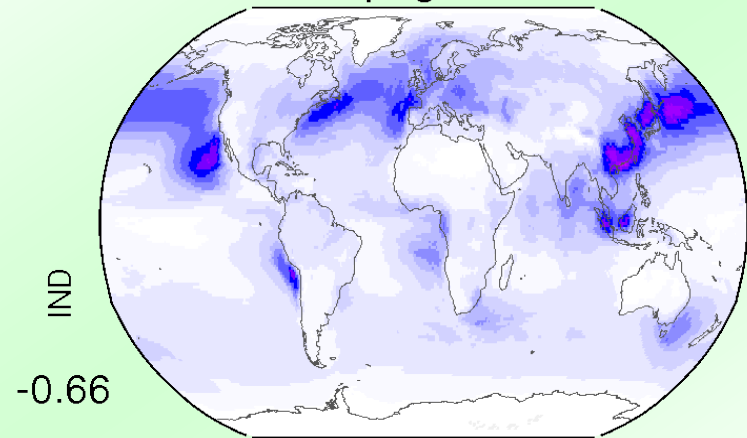
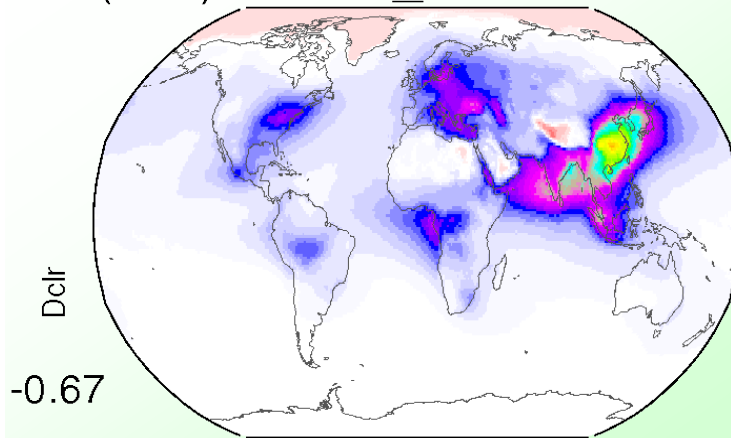
direct vs indirect - AC2

today's TOA effects

Indirect > direct (2:1)

(ann) toa net flux MACv2

2005 anthropogenic



direct
clear-
sky
Dclr

direct
all-sky
Dall

Indi-
rect
ind

total
com
(dir +
Indir)

direct vs indirect - AC2

today's atm and surface effects

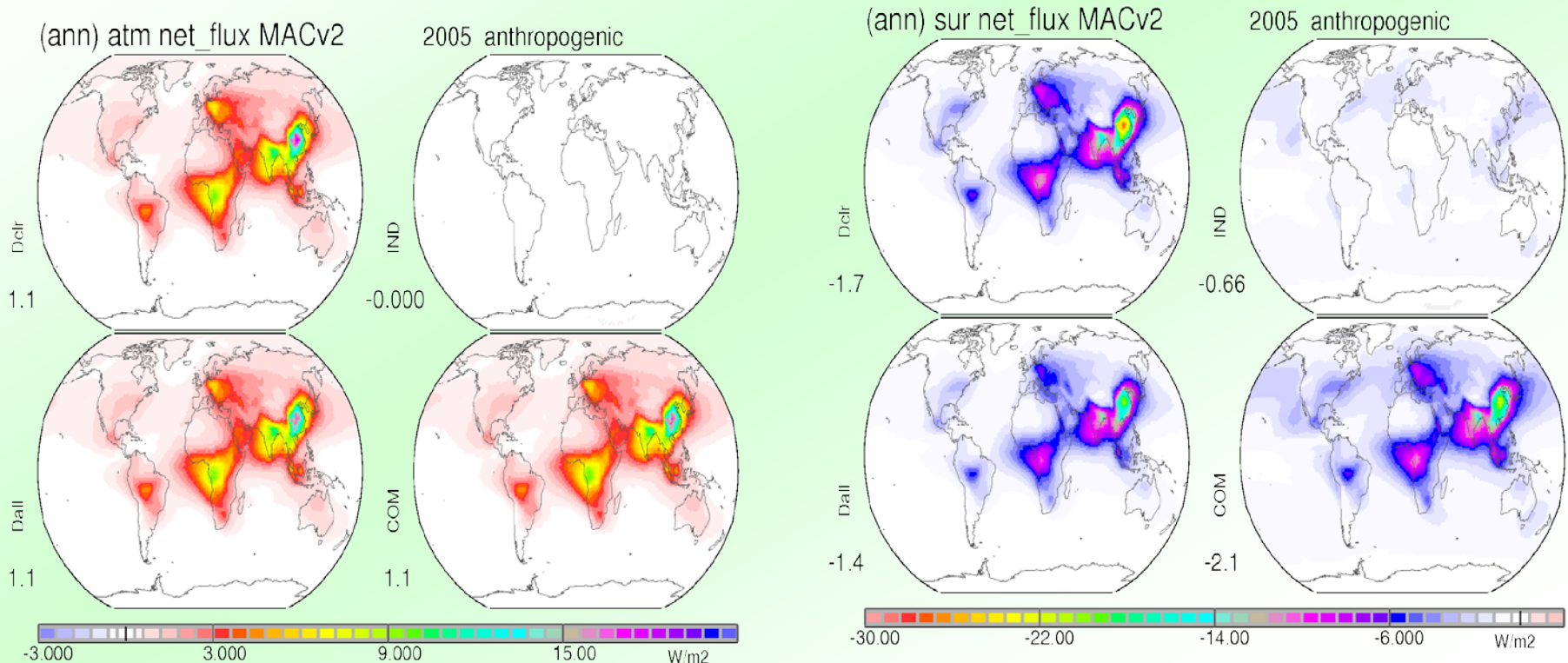
In atmosphere

direct only (+1.1W/m²)

Dclr / ind
Dall / com

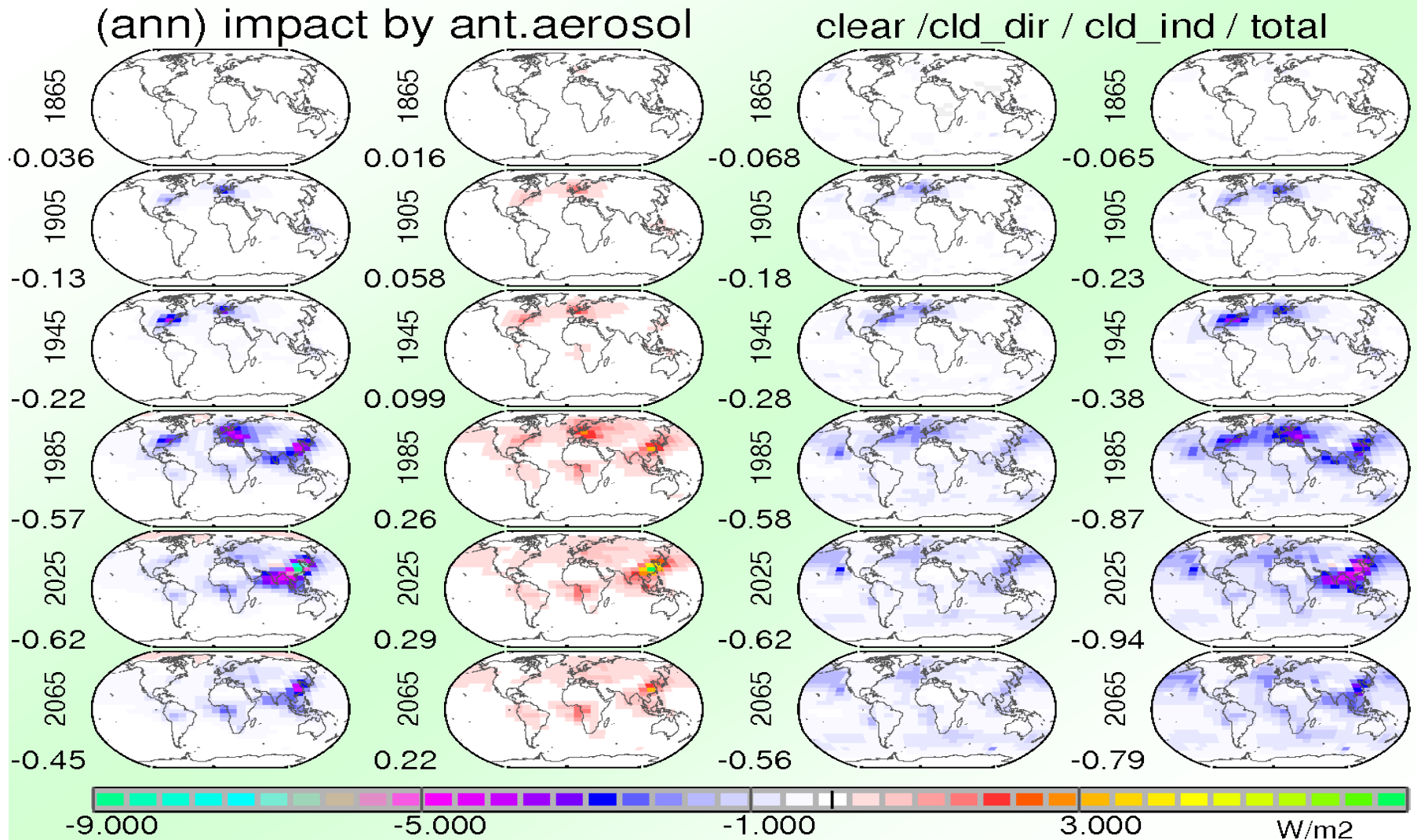
at surface

direct > indirect 2:1

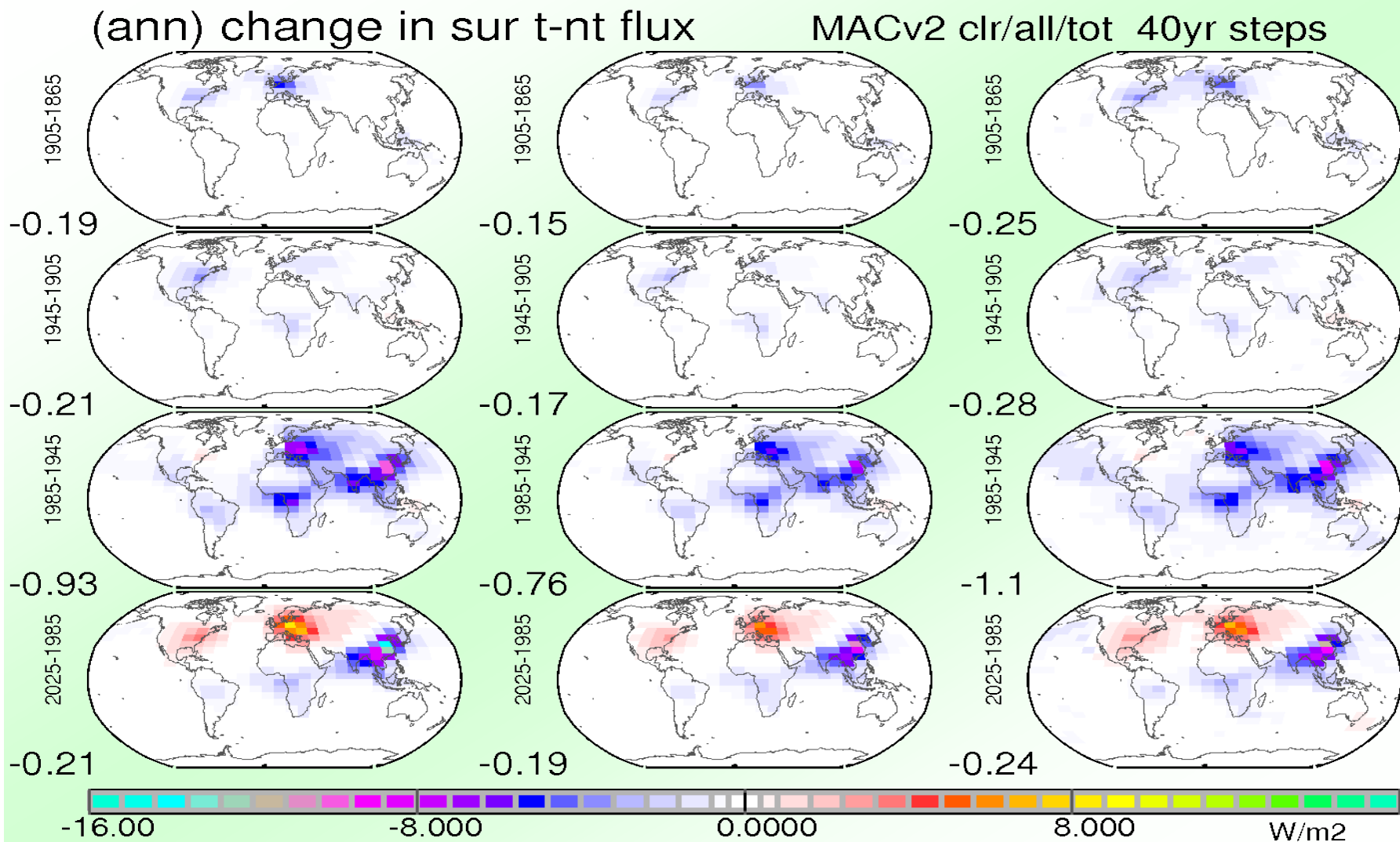


forcing over time - 1865 to 2065

clr-dir / cloud-eff / indirect / total



surface **dimming** / **brightening** clear-sky / all-sky / combined (40yr ch.)



by annual W/m² numbers

- today's anthropogenic aerosol effects
- TOA direct effects (-0.20 to -0.40 W/m²)
 - -0.35 W/m²
 - could be less if BC ant fraction is higher
 - could be lower if FI ant fraction is higher
- TOA indirect effects (-0.50 to -1.20 W/m²)
 - - 0.65 W/m²
 - could be larger if FI ant fraction is higher
- TOA BC direct effects (+0.25 to +0.45 W/m²)
 - +.28 W/m²
 - could be larger if BC_ant_frac > FI_ant_fr

summary

- **today's global forcing is at a global maximum**
- **forcing strength depends on 'anthropogenic' definition – especially for the indirect effect**
- **indirect forcing dominates at TOA ... and was early-on relative stronger than direct forcing**
- **atmospheric forcing (sol heat) is a direct effect**
- **direct forcing dominates at the surface**
- **there is significant spatial and temporal inhomogeneity for all aerosol radiative effects**

extra slides

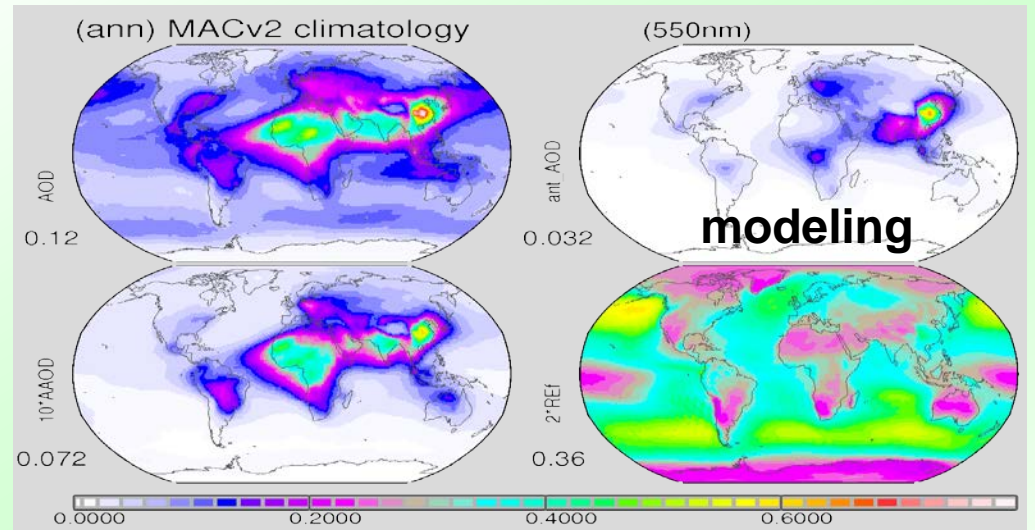
- **extras**

the MACv2 climatology

monthly 1x1 maps (←AERONET +modeling)

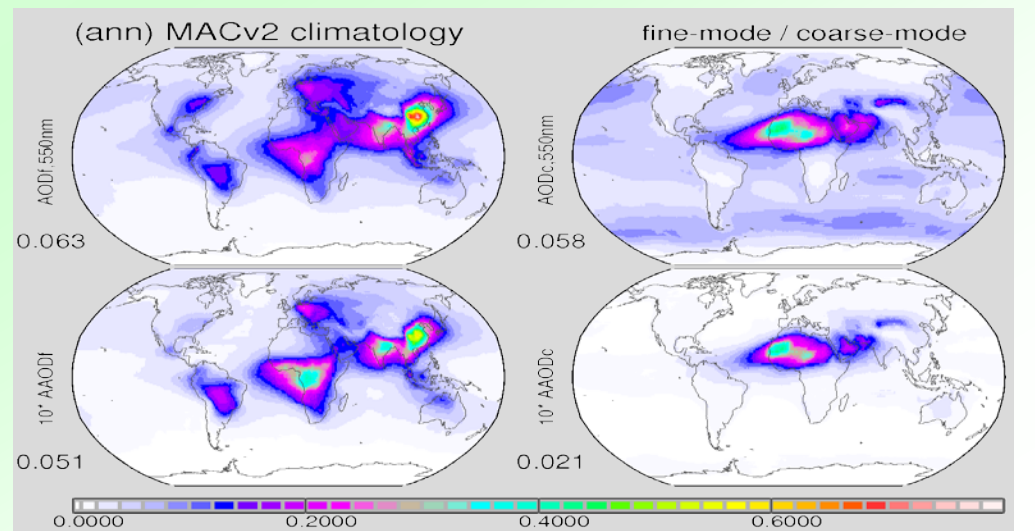
- annual maps →

- AOD 550nm
- 10* AAOD 550nm
- antAOD 550nm
- 2* REf [um]



- annual maps →

- AODf 550nm
- 10* AAODf 550nm
- AODc 550nm
- 10* AAODc 550nm



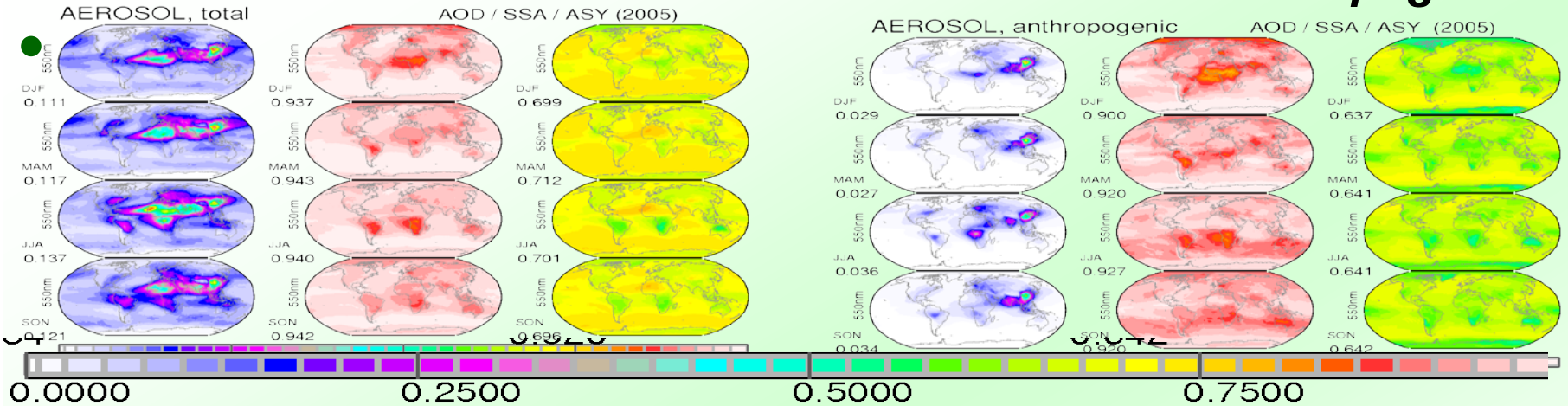
component choice

- **fine mode AOD 550nm**
 - **SU, OC or BC**
 - **fine mode AAOD 550nm**
 - **strong abs → BC (+OC shell) re = 0.12 um**
 - **weak abs → OC [OC > 5*BC] re = 0.12 um**
 - **non abs → SU re= 0.06 to 0.5 um (← REf)**
- **coarse mode AOD 550nm**
 - **DU or SS**
 - **coarse mode AAOD 550nm**
 - **weak absorption → smaller & less dust**
 - **larger absorption → larger & more dust**
 - **no absorption → SS (SS, AODmin over ocean req)**

MACv2 - spectral AOD / SSA / ASY

total

anthropogenic

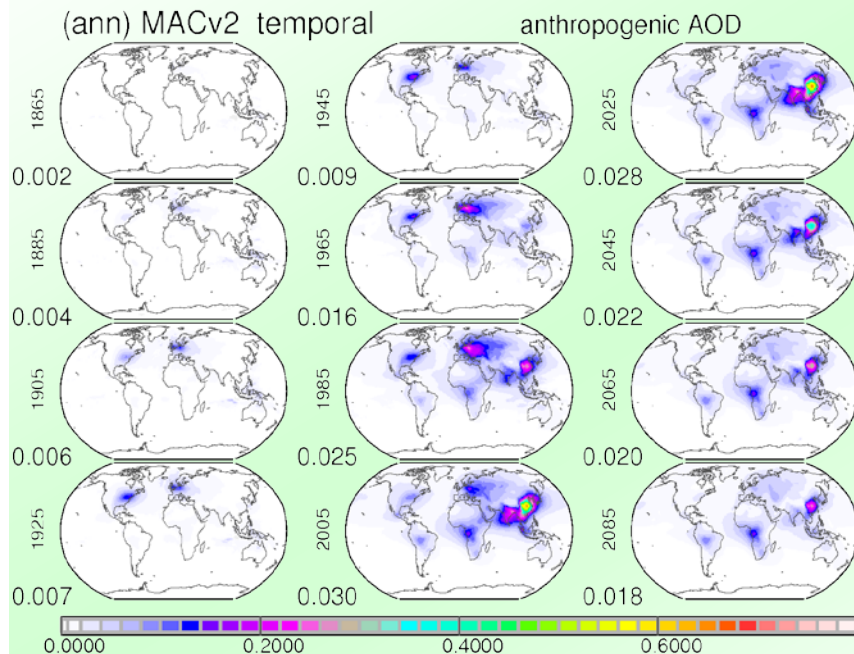


	AOD				SSA			ASY		
l(um)	total	coars	fine	anthr	total	coars	fine	total	coars	fine
.45	.144	.058	.087	.043	.902	.905	.900	.718	.789	.670
.55	.122	.058	.063	.032	.941	.964	.919	.702	.767	.639
1.0	.081	.062	.019	.009	.956	.982	.870	.693	.736	.533
10	.049	.049			.580	.560		.605	.605	

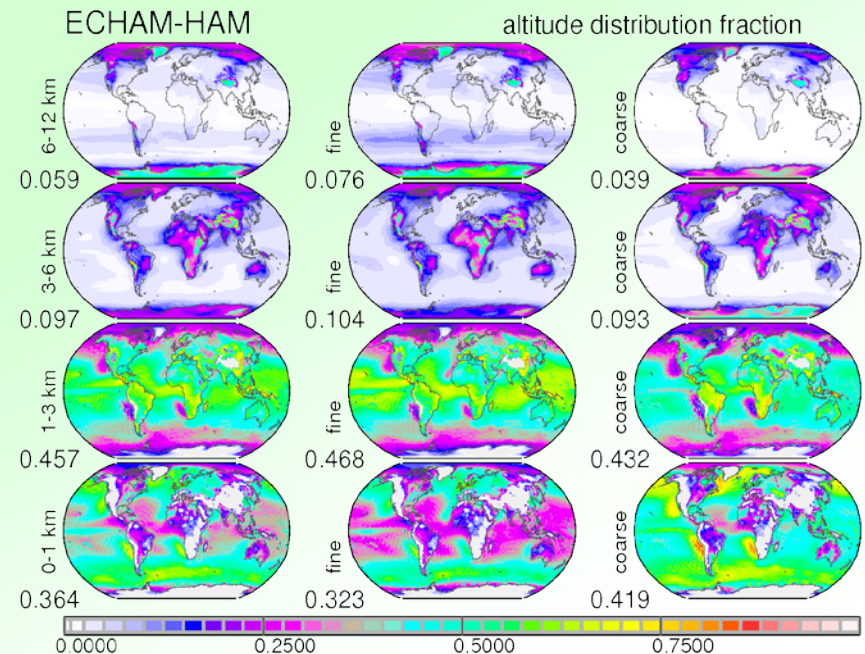
external aerosol properties

- anthropogenic (AOD-) change over time
- altitude distr. of column AOD, AOD_f and AOD_c

anthrop AOD maps 1865 to 2085



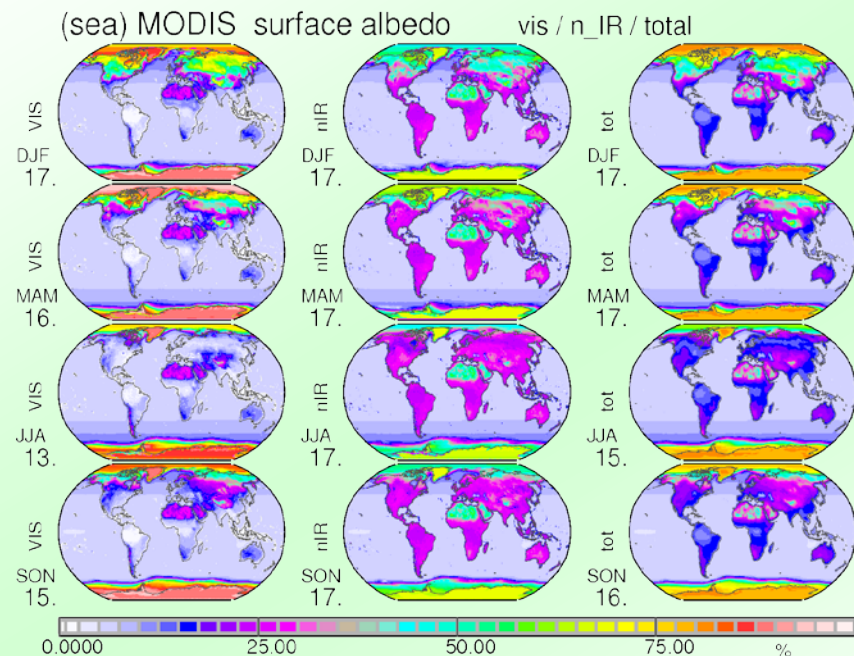
AOD fraction: 0-1, 1-3, 3-6, >6km



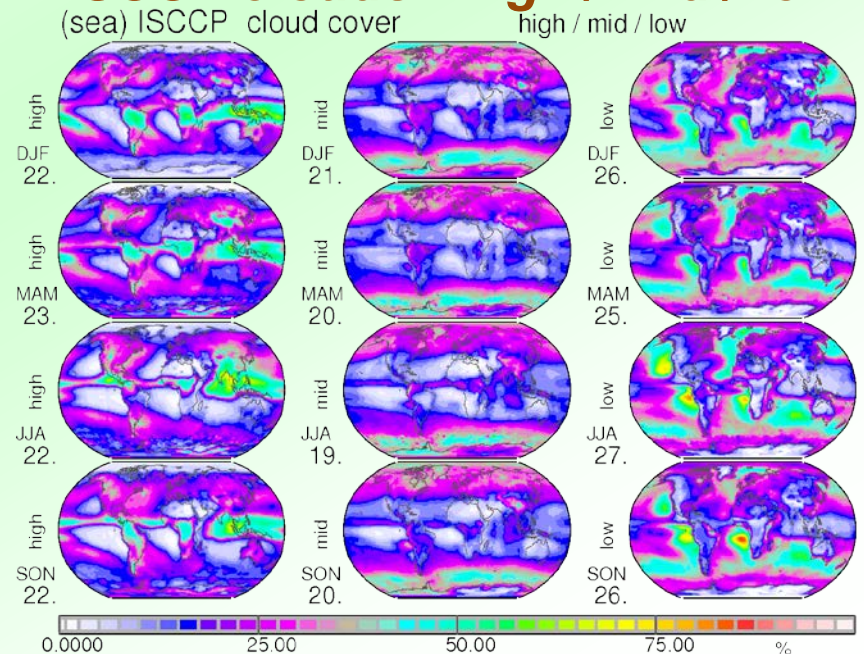
environment

- 2 stream rad. transfer - 20 bands (8sol, 12IR)
 - monthly 1x1 IPA calculation, 9 diff sun elev
 - clouds: 8 H/M/L cloud cover permutations

'MODIS' albedo: VIS / n-IR / total



ISCCP clouds: high / mid / low

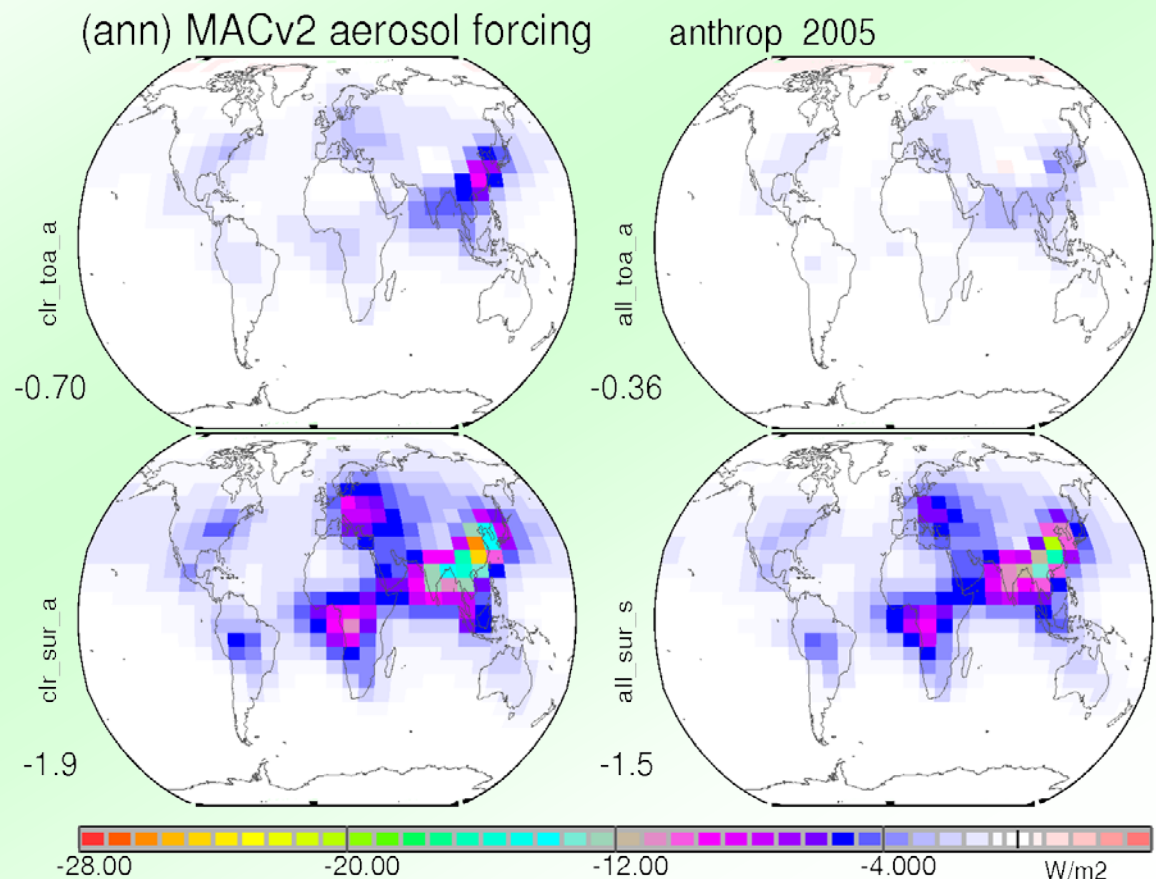
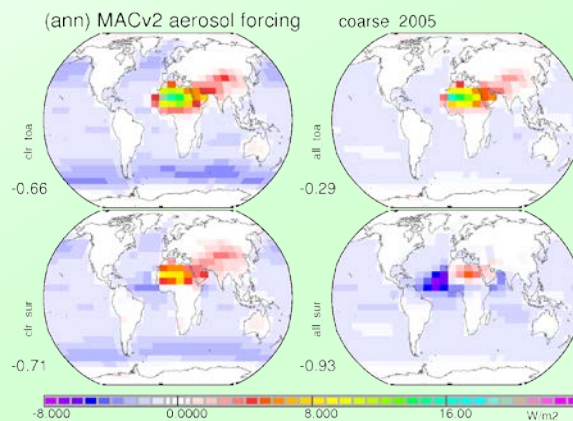
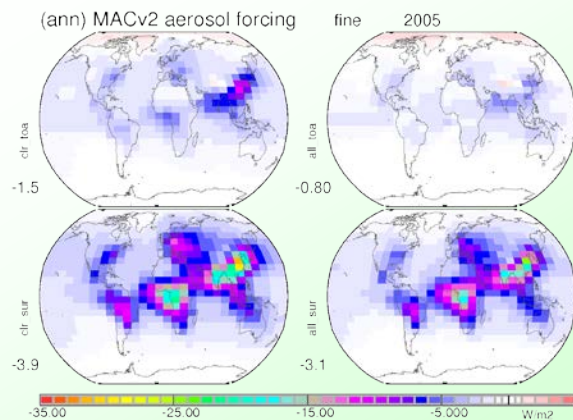


**TOA, clear / TOA, all
surf, clear / surf all**

direct effects

• **fine & coarse**

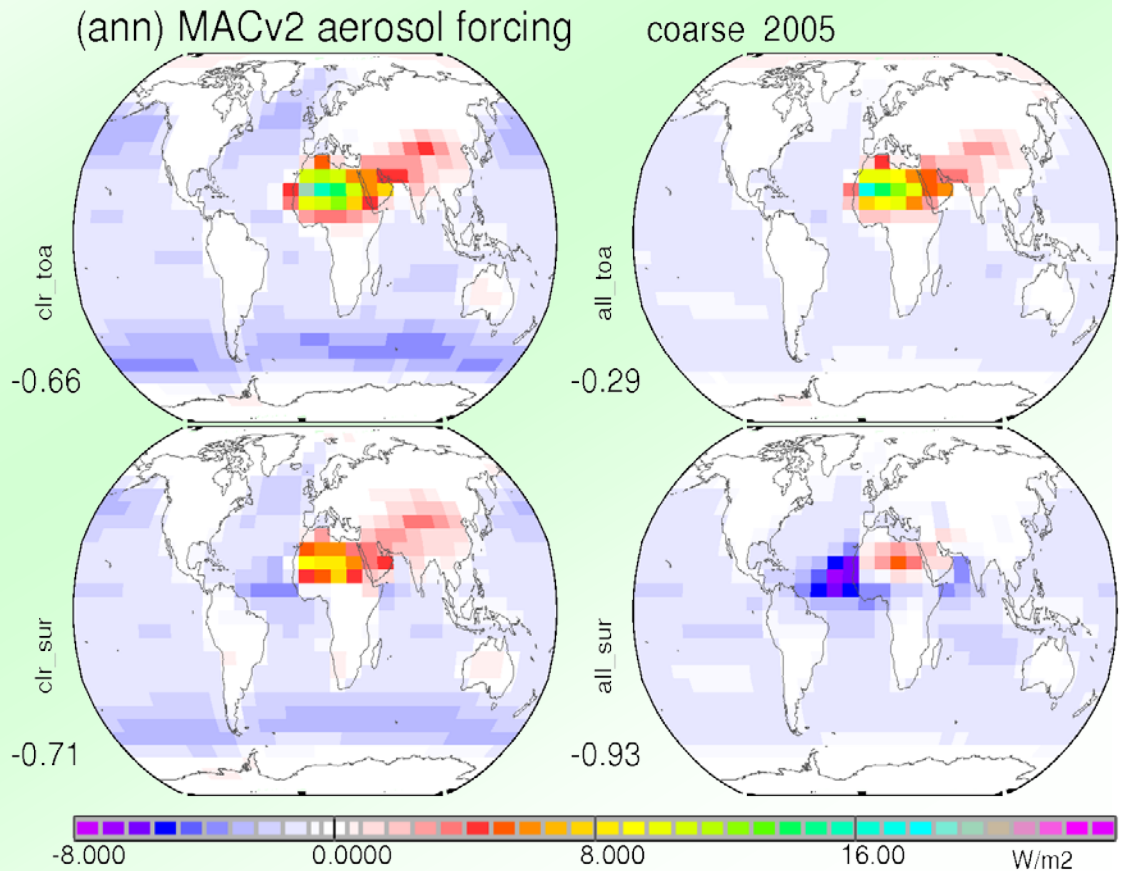
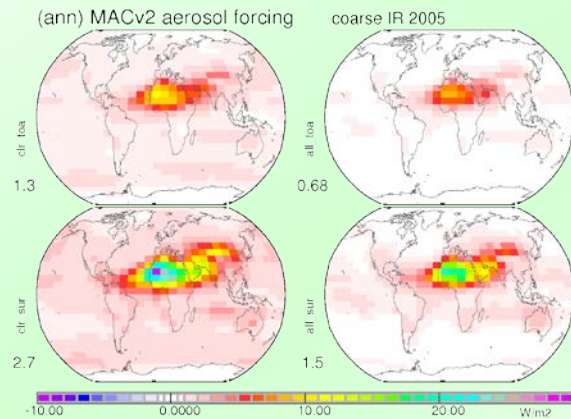
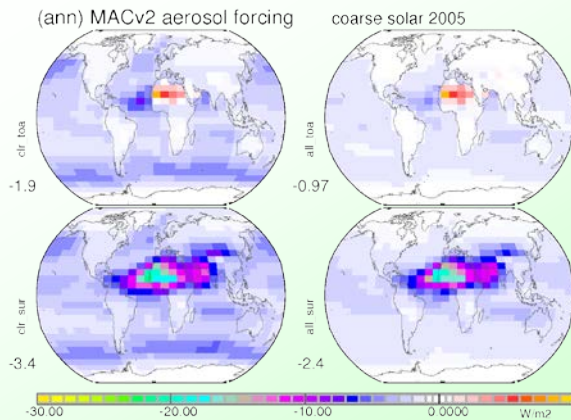
anthropogenic



coarse AOD rad. effects

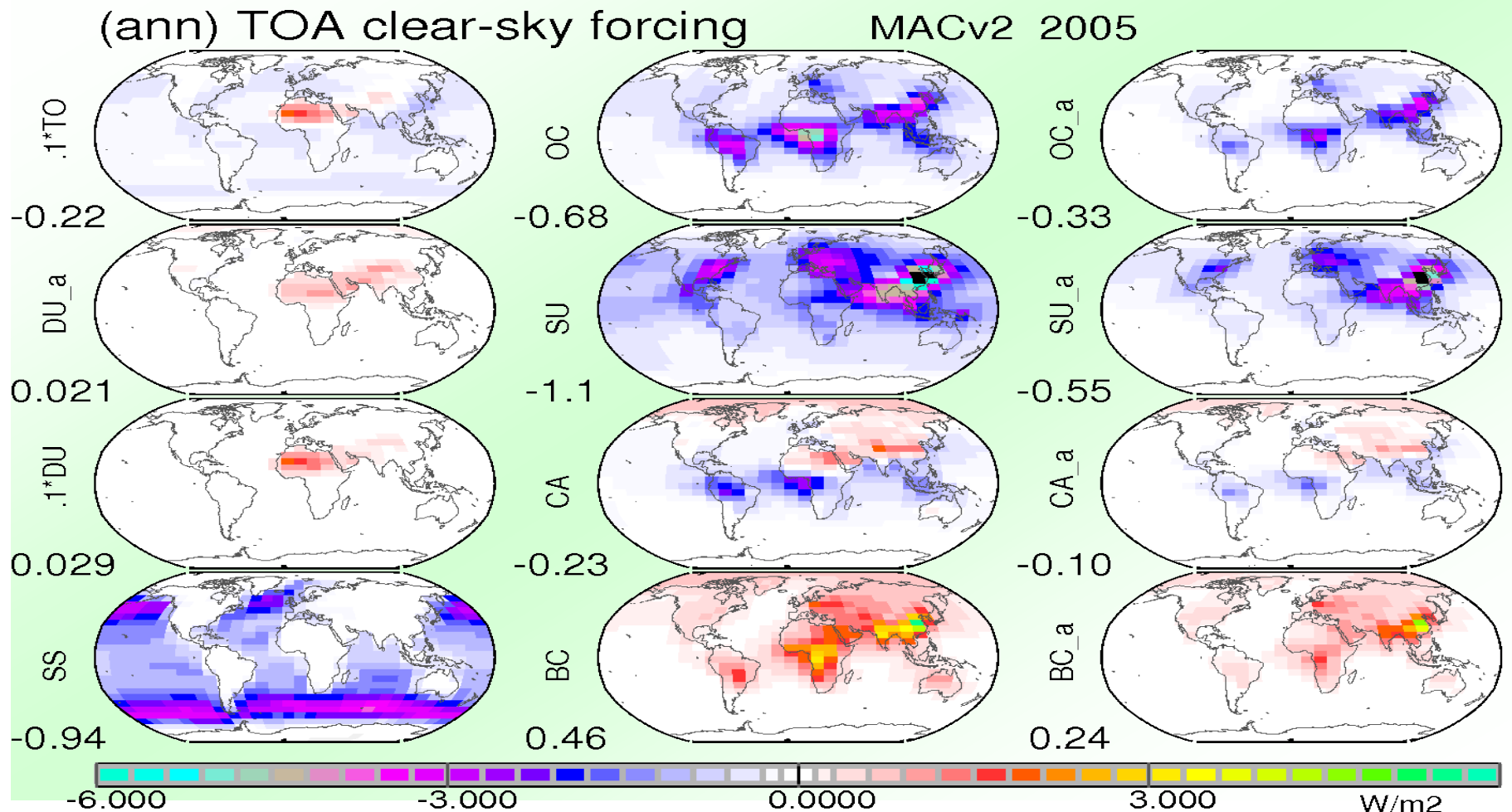
- solar & IR

total



component rad.effects

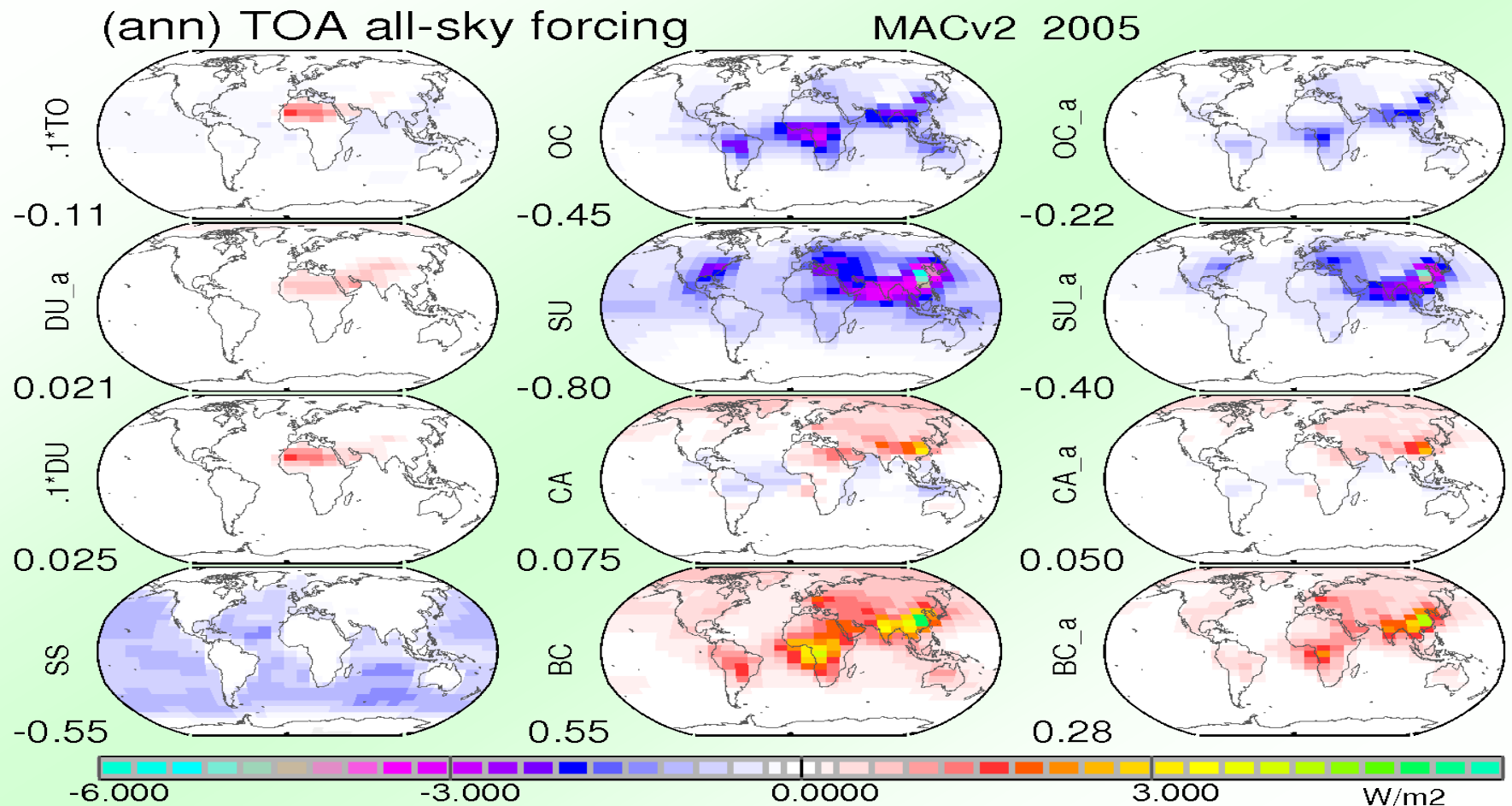
- **clear-sky (today) OC/SU/BC/CA/DU/SS +anthr**



component rad.effects

BC ant: 0.28 to 0.44 W/m² (← what is BC ant fraction?)

- all-sky (today) OC/SU/BC/CA/DU/SS +anthr



annual averages

direct effect (W/ m2)	TOA				ATMOSPHERE				SURFACE			
	Total		anthr		total		anthr		Total		anthr	
	all	clear	all	clear	all	clear	all	clear	all	clear	all	clear
total	-1.1	-2.2			+2.9	+2.3			-4.0	-4.5		
fine	-0.80	-1.5	-0.36	-0.70	+2.3	+2.4	+1.1	+1.2	-3.1	-3.9	-1.5	-1.9
- SU	-0.83	-1.2	-0.41	-0.58	+0.02	+0.03	+0.01	+0.01	-0.85	-1.2	-0.42	-0.59
- CA	+0.08	-0.23	+0.05	-0.10	+2.0	+2.2	+1.0	+1.1	-2.1	-2.5	-1.0	-1.2
- OC	-0.45	-0.68	-0.22	-0.33	+0.48	+0.52	+0.23	+0.25	-0.93	-1.2	-0.45	-0.57
- BC	+0.55	+0.46	+0.28	+0.24	+1.7	+1.8	+0.89	+0.93	-1.2	-1.4	-0.61	-0.69
- BC*			+0.44	+0.37			+1.4	+1.5			-0.97	-1.1
coars	-0.29	-0.66			+0.64	+0.05			-0.93	-0.71		
- SS	-0.55	-0.94			+0.00	-0.11			-0.55	-0.83		
- DU	+0.25	+0.29	+0.02	+0.02	+0.63	+0.17	+0.11	+0.03	-0.38	+0.12	-0.09	-0.01

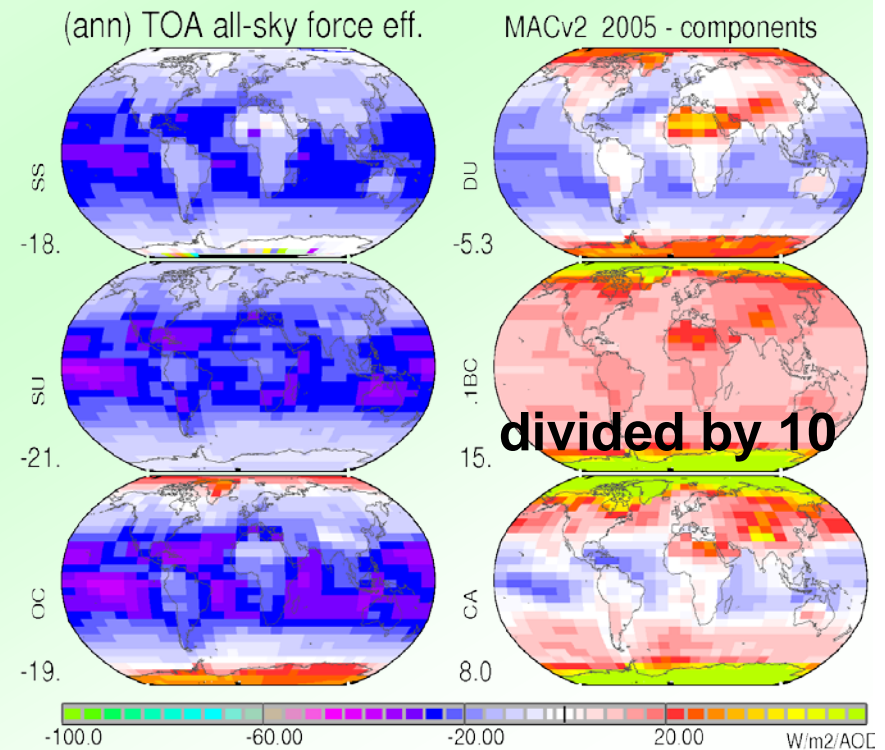
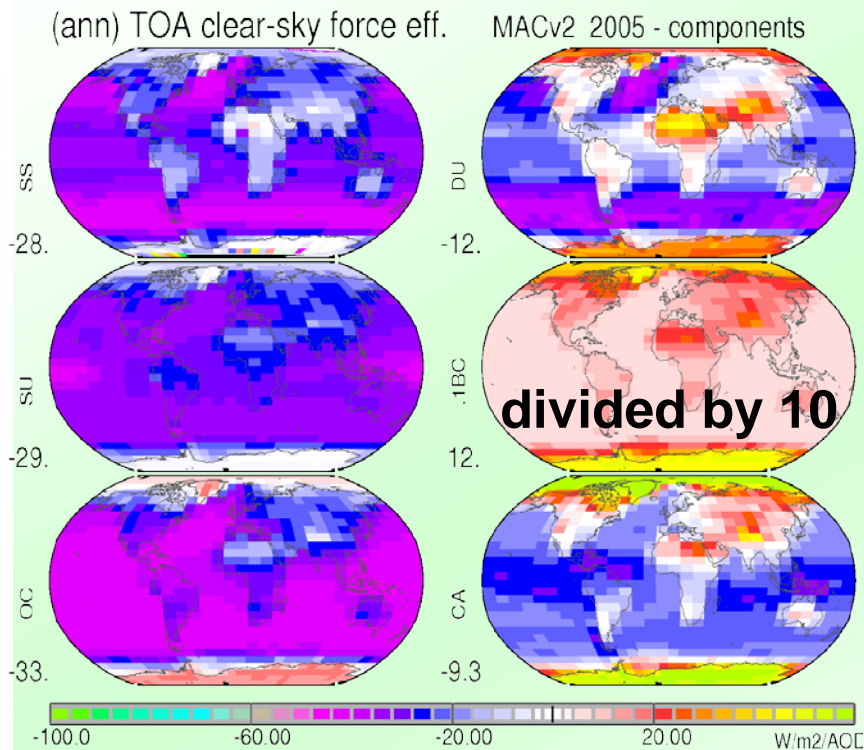
Divided by 10 10

TOA component efficiencies

- clear-sky

TO / DU
SU / BC
OC / CA

all-sky



today's indirect effect

strong impact on anthropogenic fine mode def.

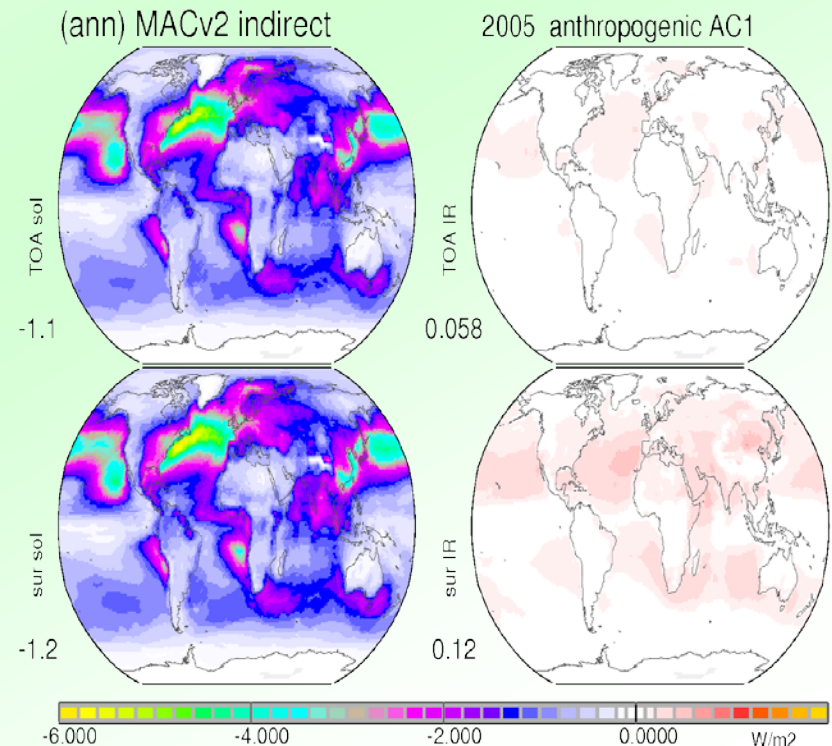
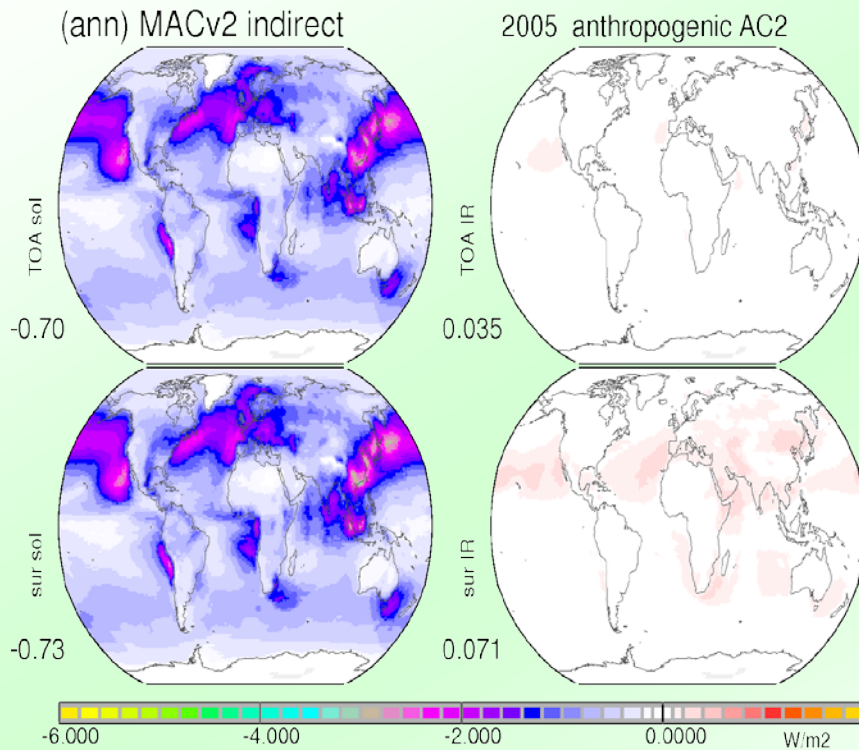
• **AeroCom2 ant**
Lamarque

TOA sol / TOA IR
surf sol / surf IR

AeroCom1 ant
Dentener

-0.66 W/m²

-1.05 W/m²



TOA forcing – 40 year period change

clear-sky / all-sky / combined

