simple aerosol representations in a global and seasonal context to address aerosol **direct** and **indirect** radiative effects

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overview

- it's about regional and seasonal distributions
  (although also global averages are calculated)

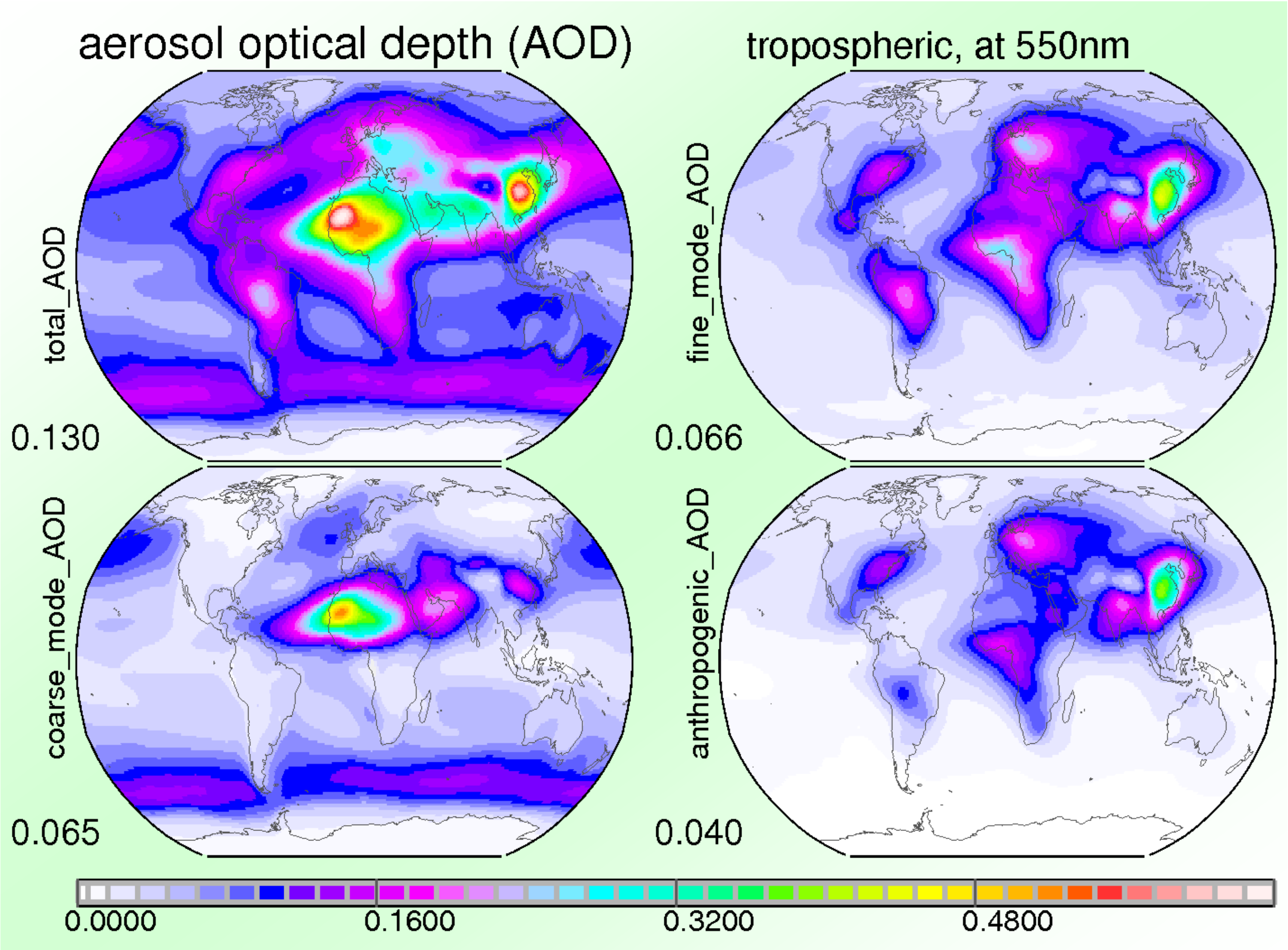
- aerosol climatology
  - amount, absorption, size (AOD, SSA, ASY)
  - associated CCN (and IN)

- aerosol radiative impacts
  – aerosol direct effect - 0.35 W/m2 (TOA, all-sky)
  – aerosol indirect effect - 0.75 W/m2 (TOA, all-sky)

  … and the combined effect is smaller than the sum

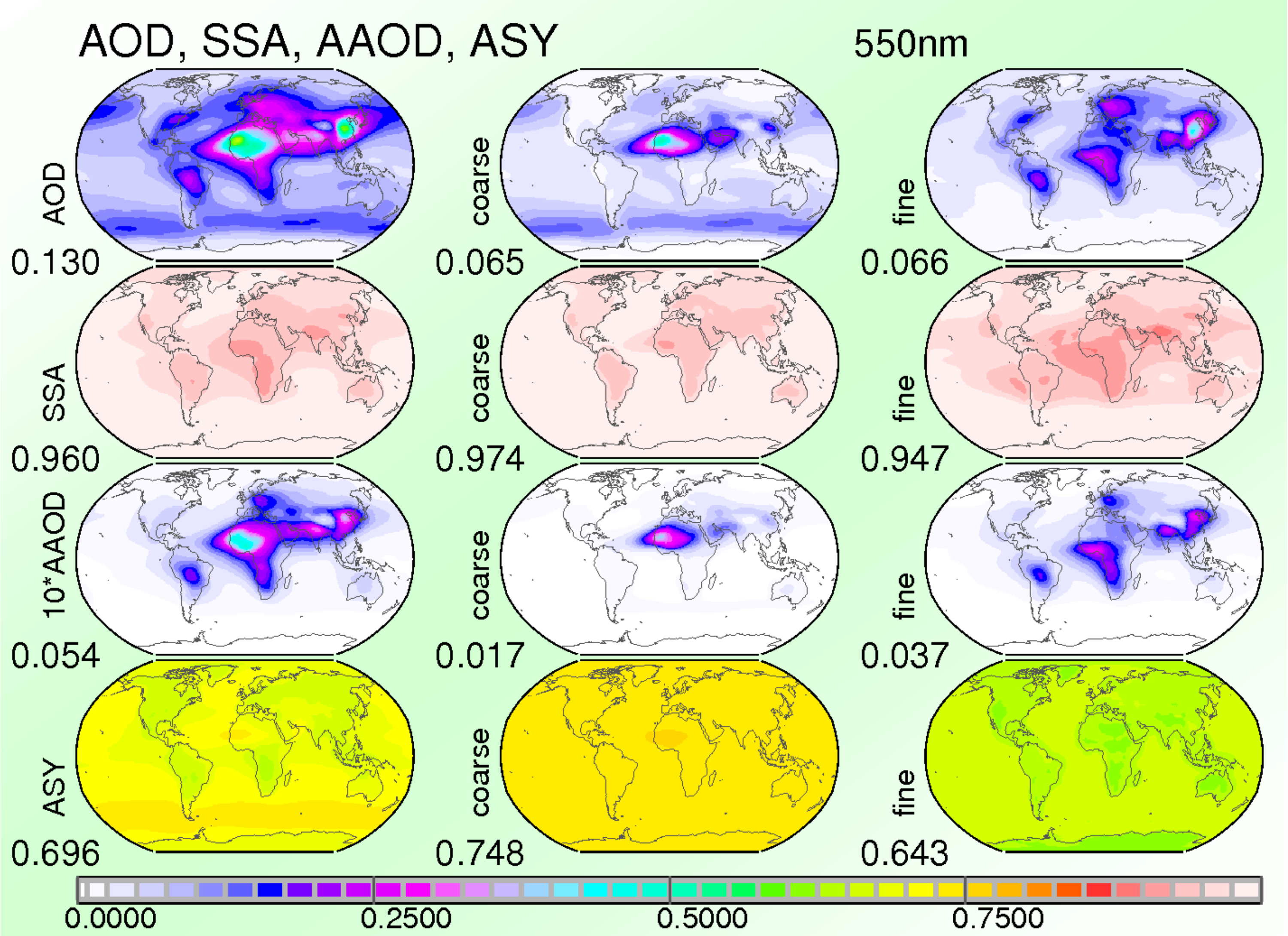
AOD climatology

half in coarse sizes (>1μm) – half in fine sizes (<1μm)



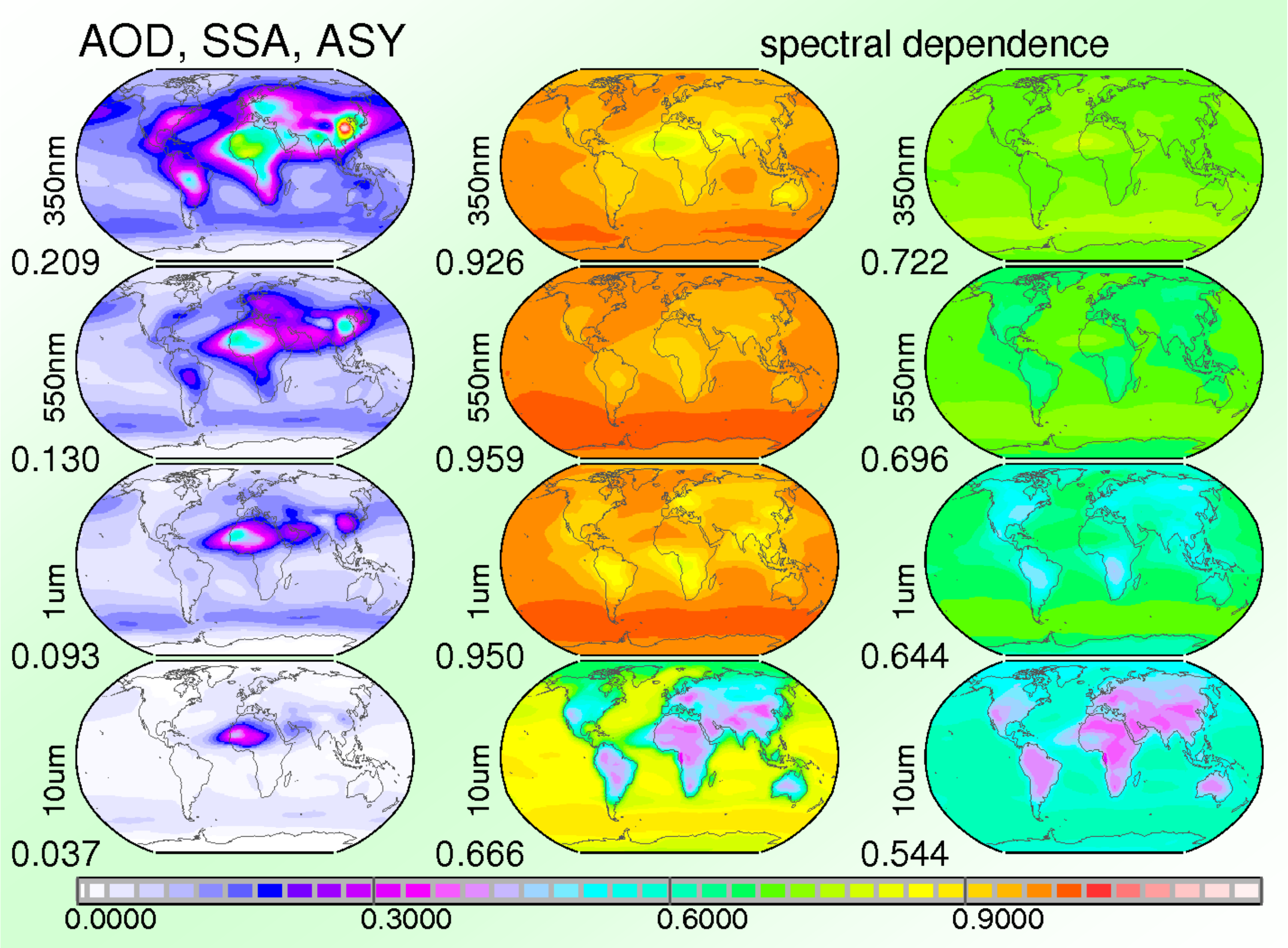
total vs. coarse vs. fine

input for radiative transfer simulations



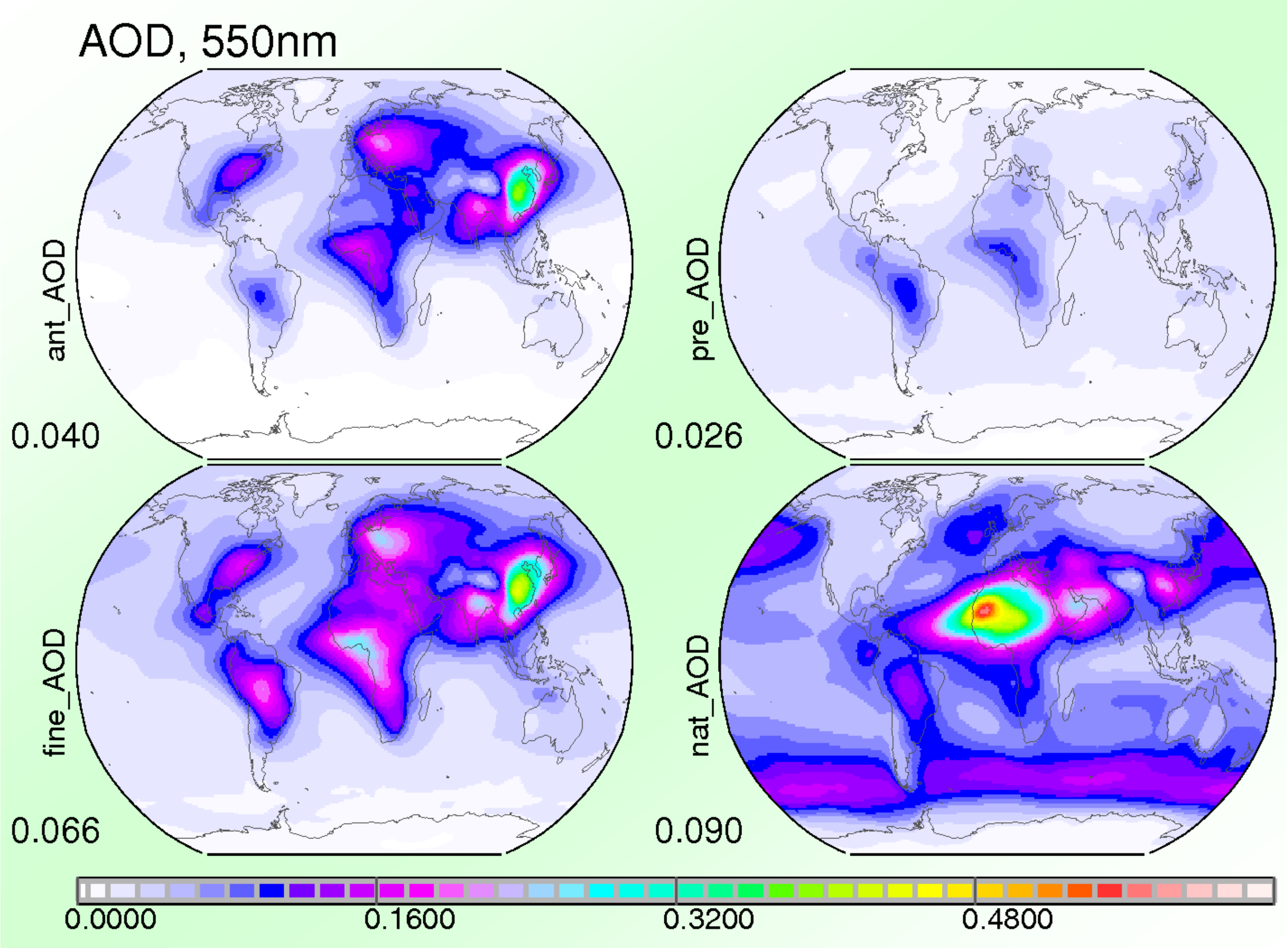
amount / not absorbed / size

input for radiative transfer simulations



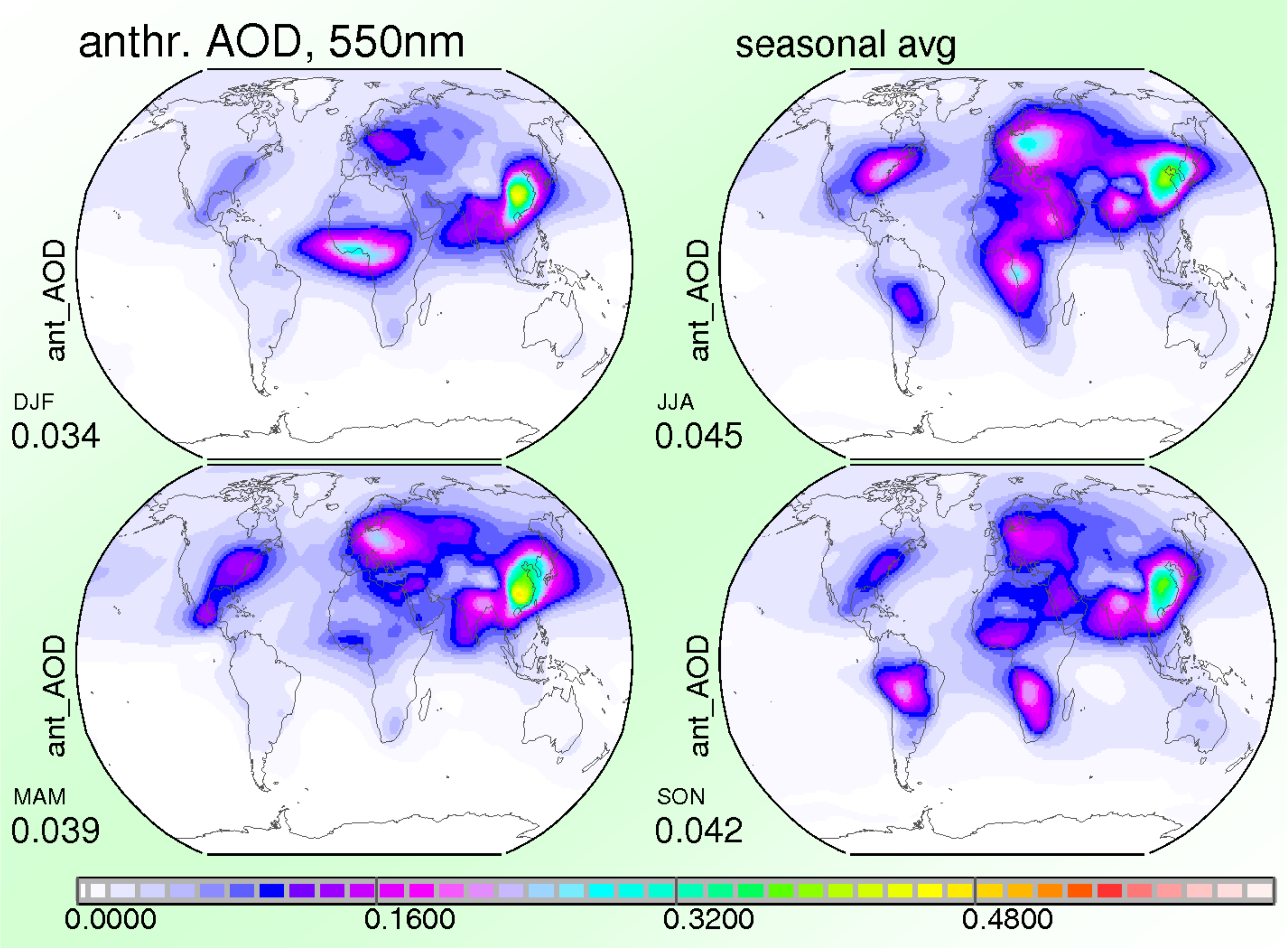
AOD: natural vs anthropogenic

~ 2 (.09) to 1 (.04) ratio



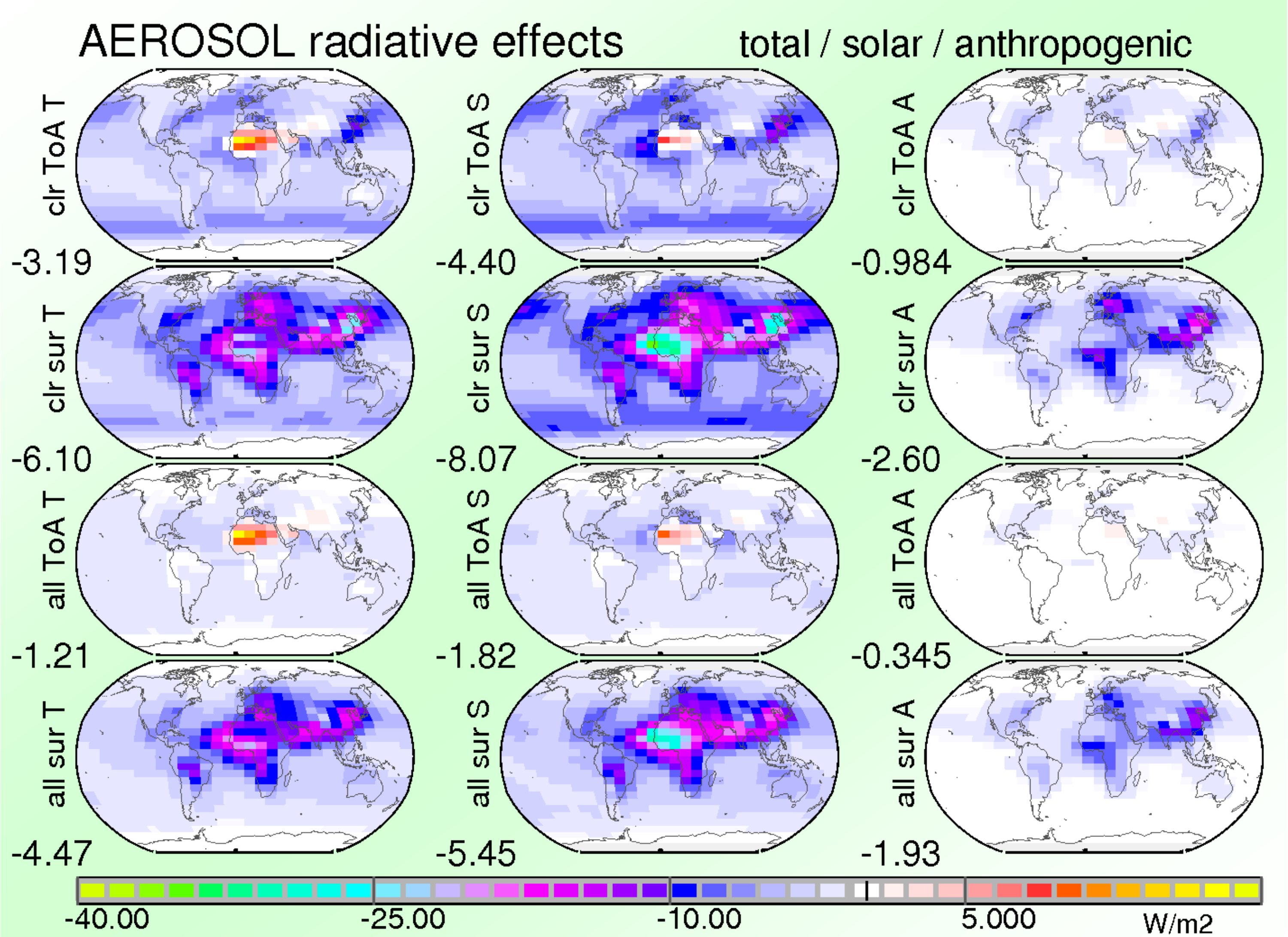
anthropogenic AOD

highest during NH summer



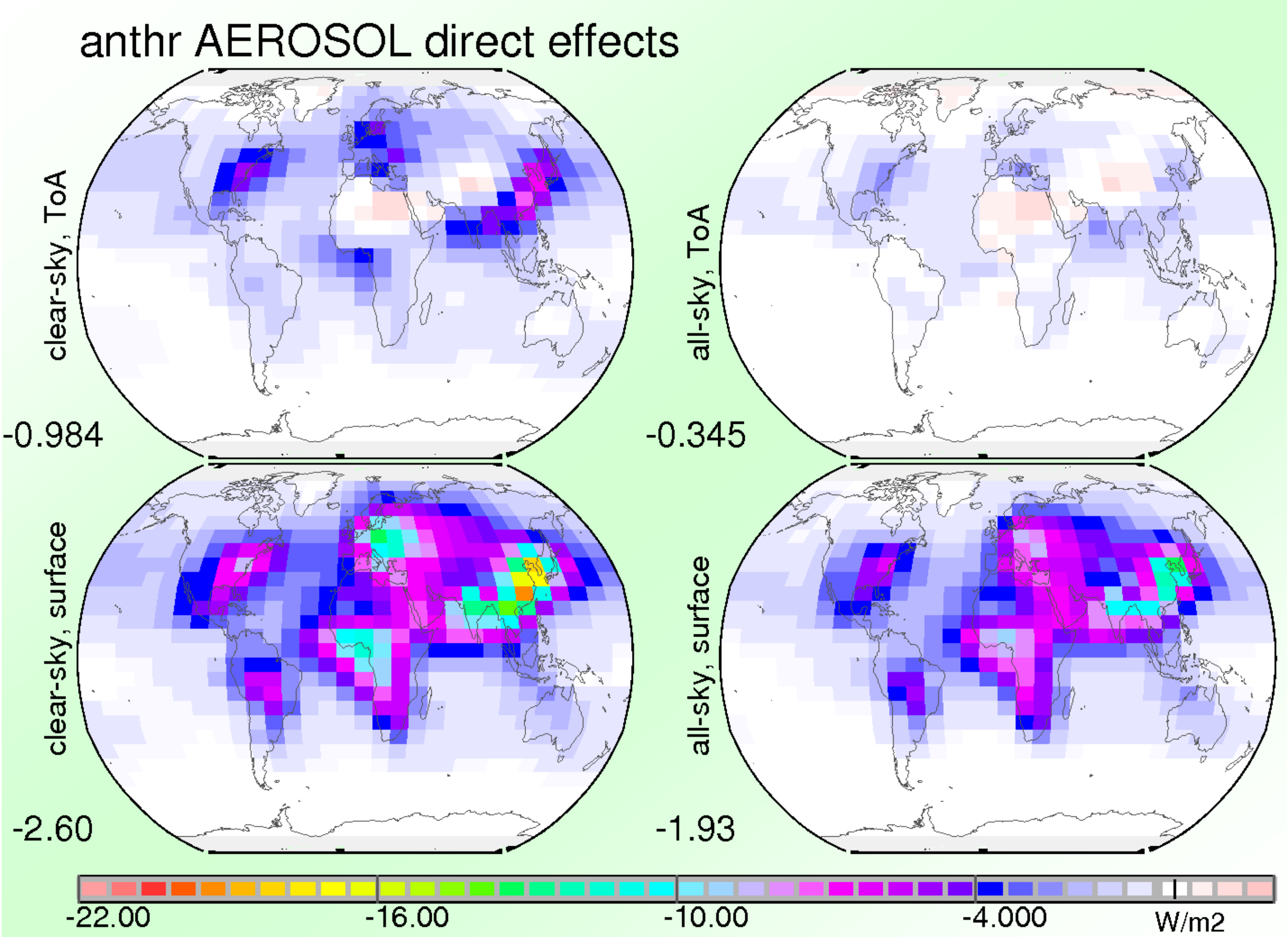
direct radiative effects

overview with annual maps



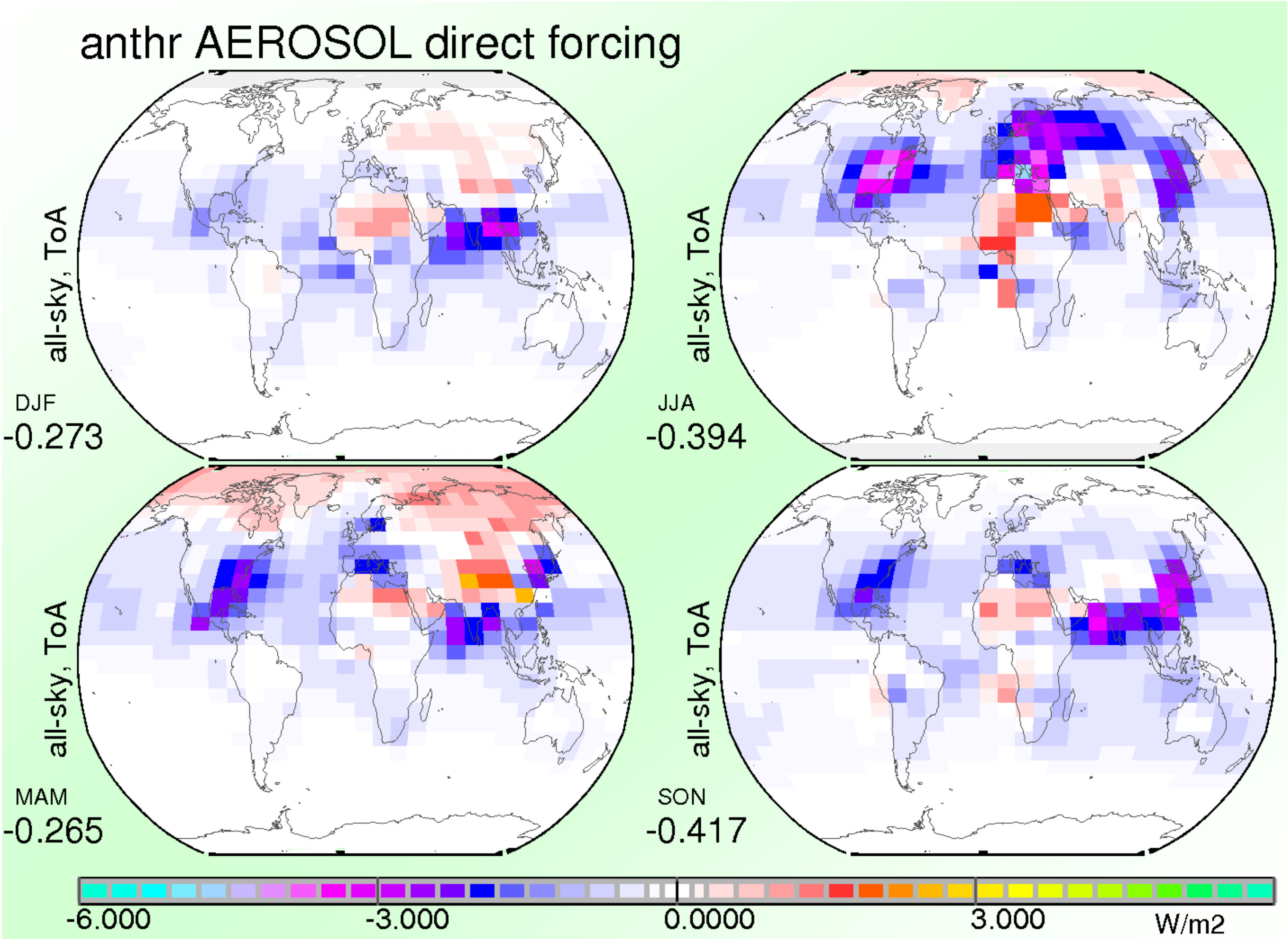
direct anthropogenic effects

clear-sky vs all-sky … TOA vs surface



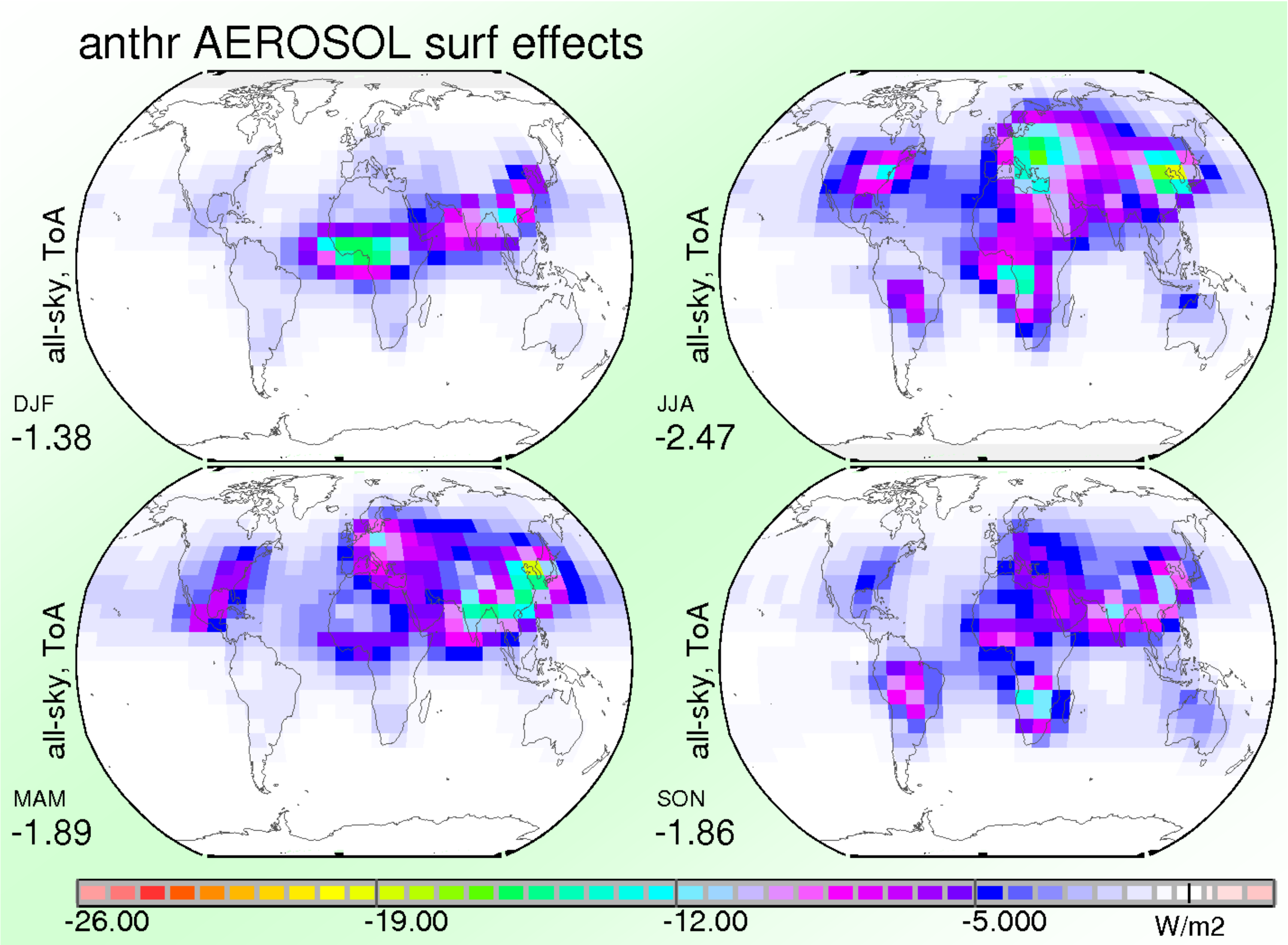
direct forcing: … - 0.35 W/m2

strongest regional contrasts in NH spring



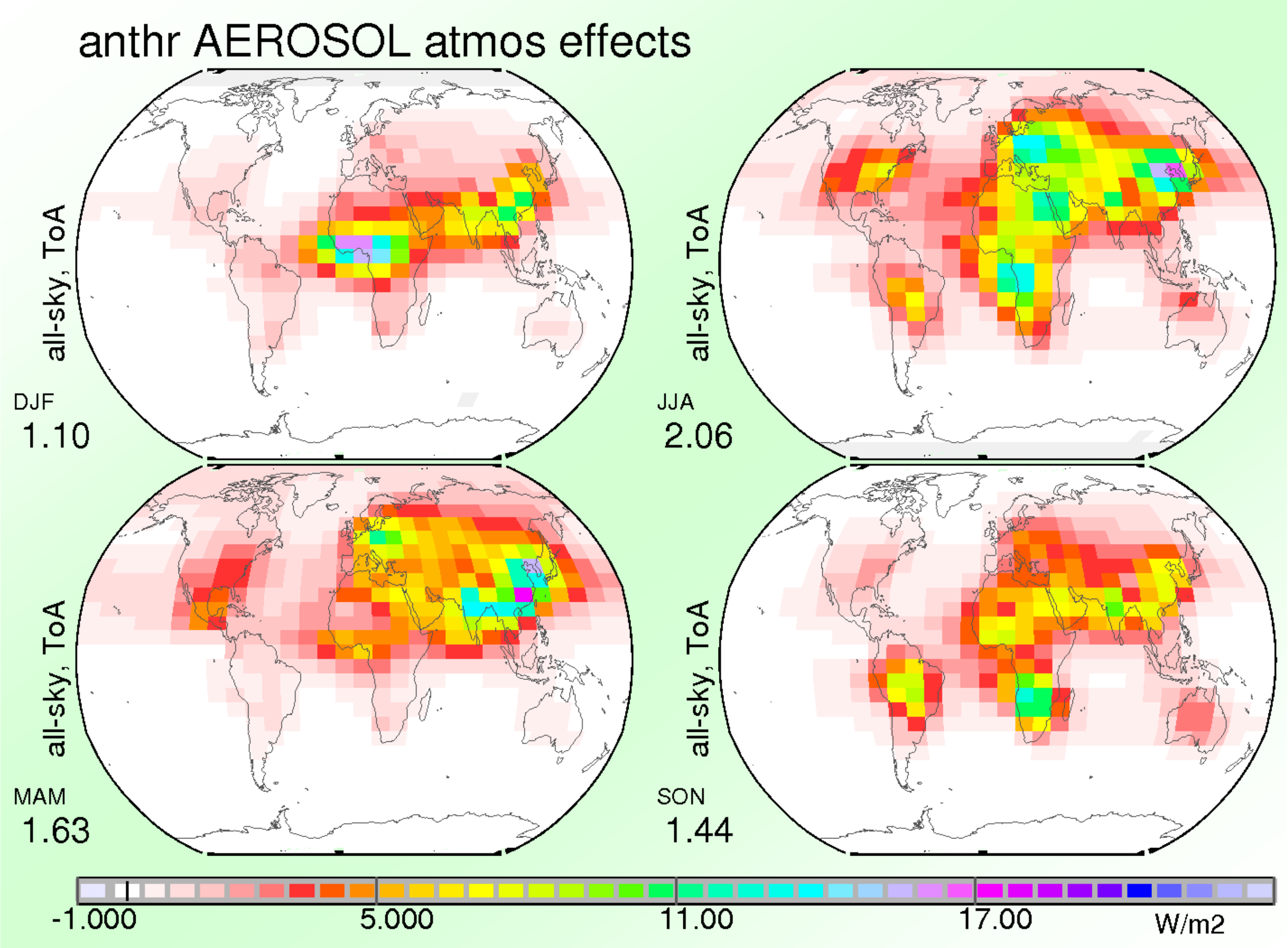
surface effect: - 1.9 W/m2

strongest reductions in NH summer



atmos effect: + 1.6 W/m2

solar warming by anthropogenic aerosol



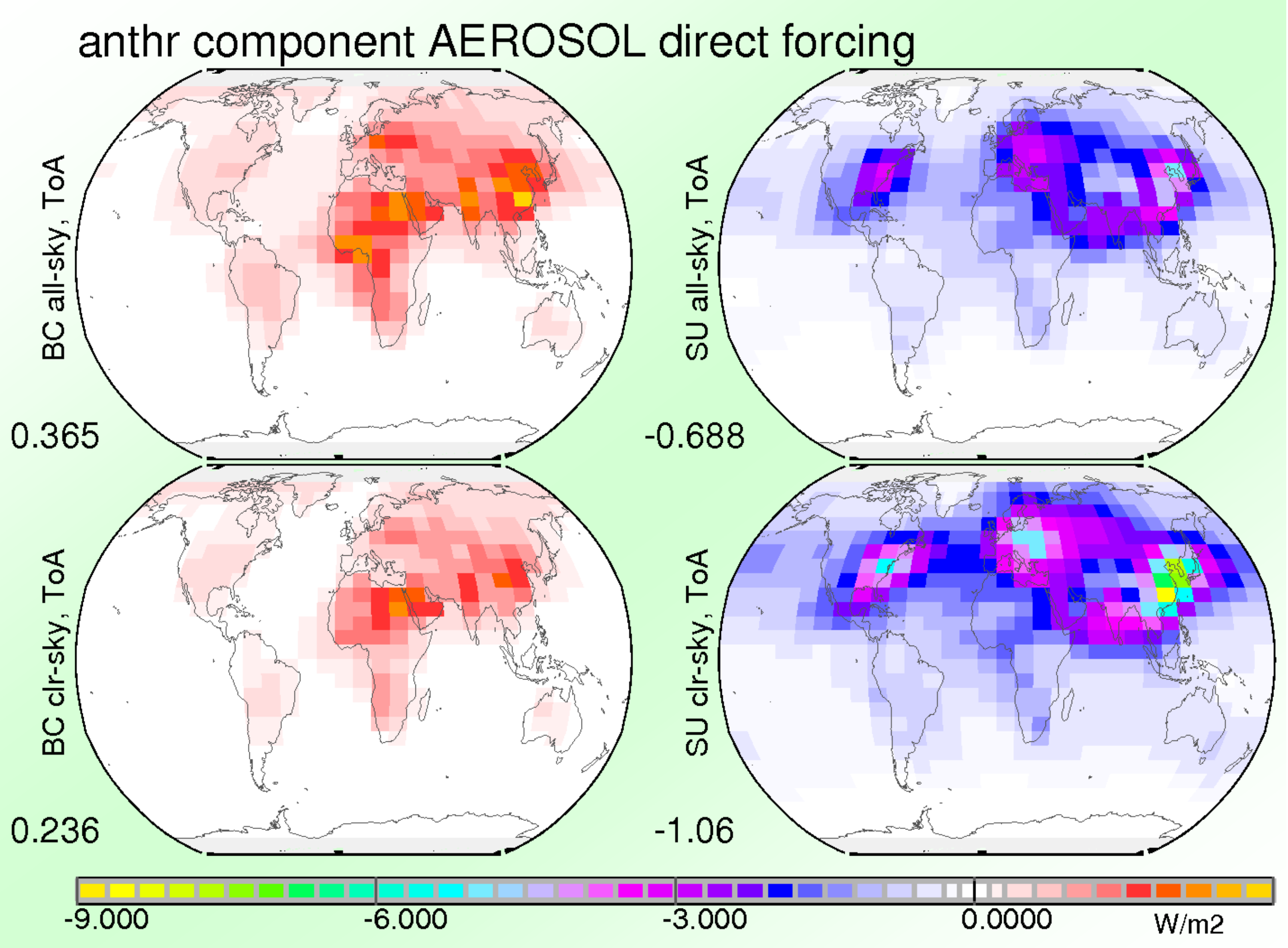
BC sensitivities

- estimating forcing component contributions
- BC
  - translate all fine-mode absorption in BC-AOD
    - too high … ignoring OC contribution
    - too low … ignoring BC contributions in the coarse size mode
- BC forcing estimates
  - clear-sky + 0.25 W/m2
  - all-sky + 0.35 W/m2

SU sensitivities

- estimating forcing component contributions
- SU
  - multiply the anthr. AOD with sulfate fine-mode fraction (.040 → .024), presribe sulfate SSA
  - prescribe sulfate with r,eff=0.2μm for .024 AOD
- SU forcing estimates
  - clear-sky - 1.0 W/m2
  - all-sky - 0.7 W/m2

sensitivities



indirect radiative effects

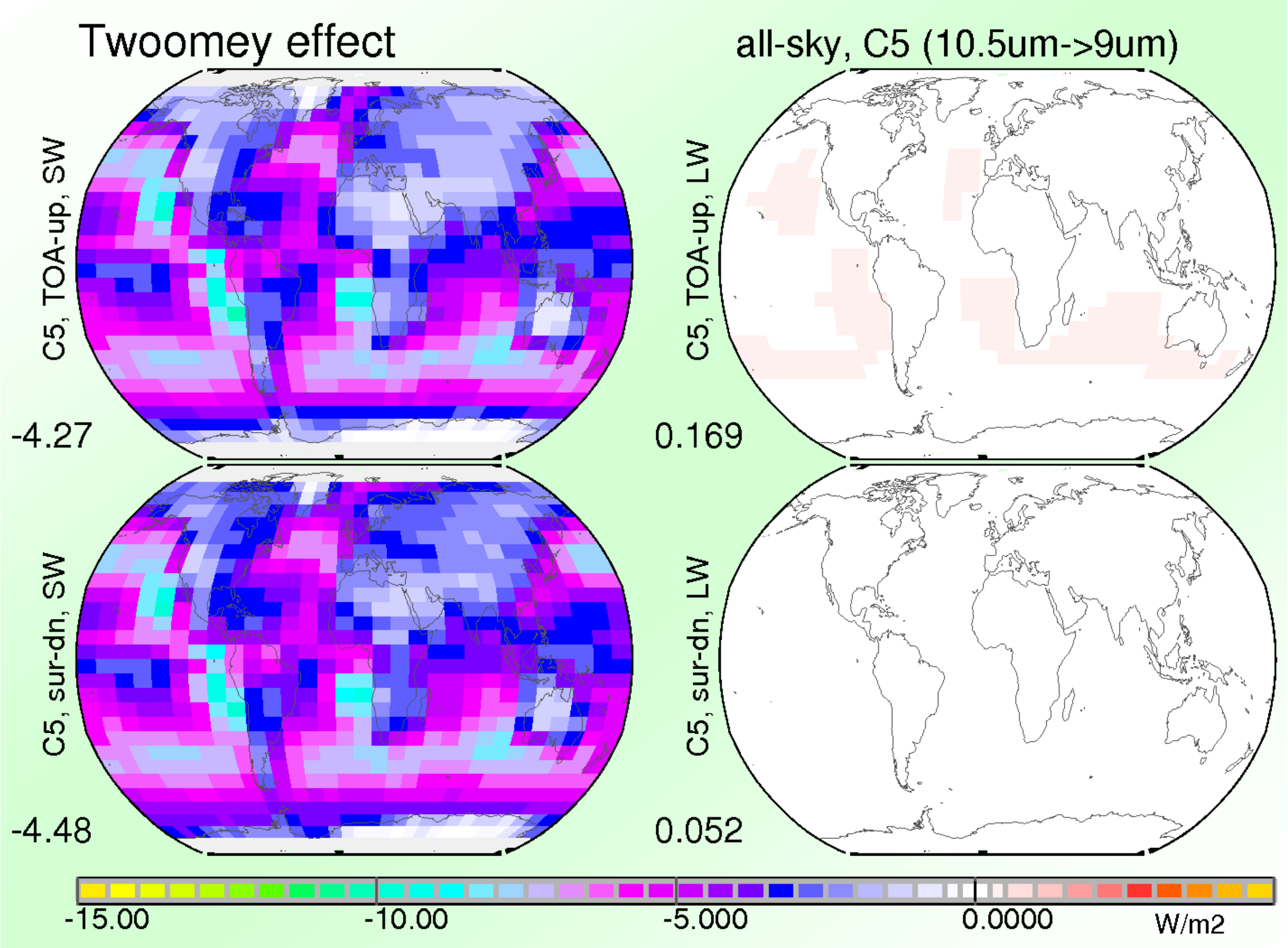
- simple sensitivities … what if
  - low cloud droplet # is evenly factor-increased
    - in a 'C5' cloud from 10.5 to 9 μm: 1.75 * more drops
    - in a 'C1' cloud from 6 to 5 μm: 1.88 * more drops
    - in log-normal from 10 to 7.4 μm: 2.47 * more drops
    - In log-normal from 10 to 9.5um: 1.18 * more drops
- now with more realistic changes …
  - droplet increases … based on (tot/nat) -ratios
    - using anthrop. CCN and natural CCN at 1km
    - (ant /m3 +nat /m3) /nat /m3 *all CCN → drops* (lin)
    - ln(1+(ant+nat)/10^4) / ln(1+nat/10^4) (ln4)

choice

- ln(1+(ant+nat)/10^5) / ln(1+nat/10^5) (ln5)

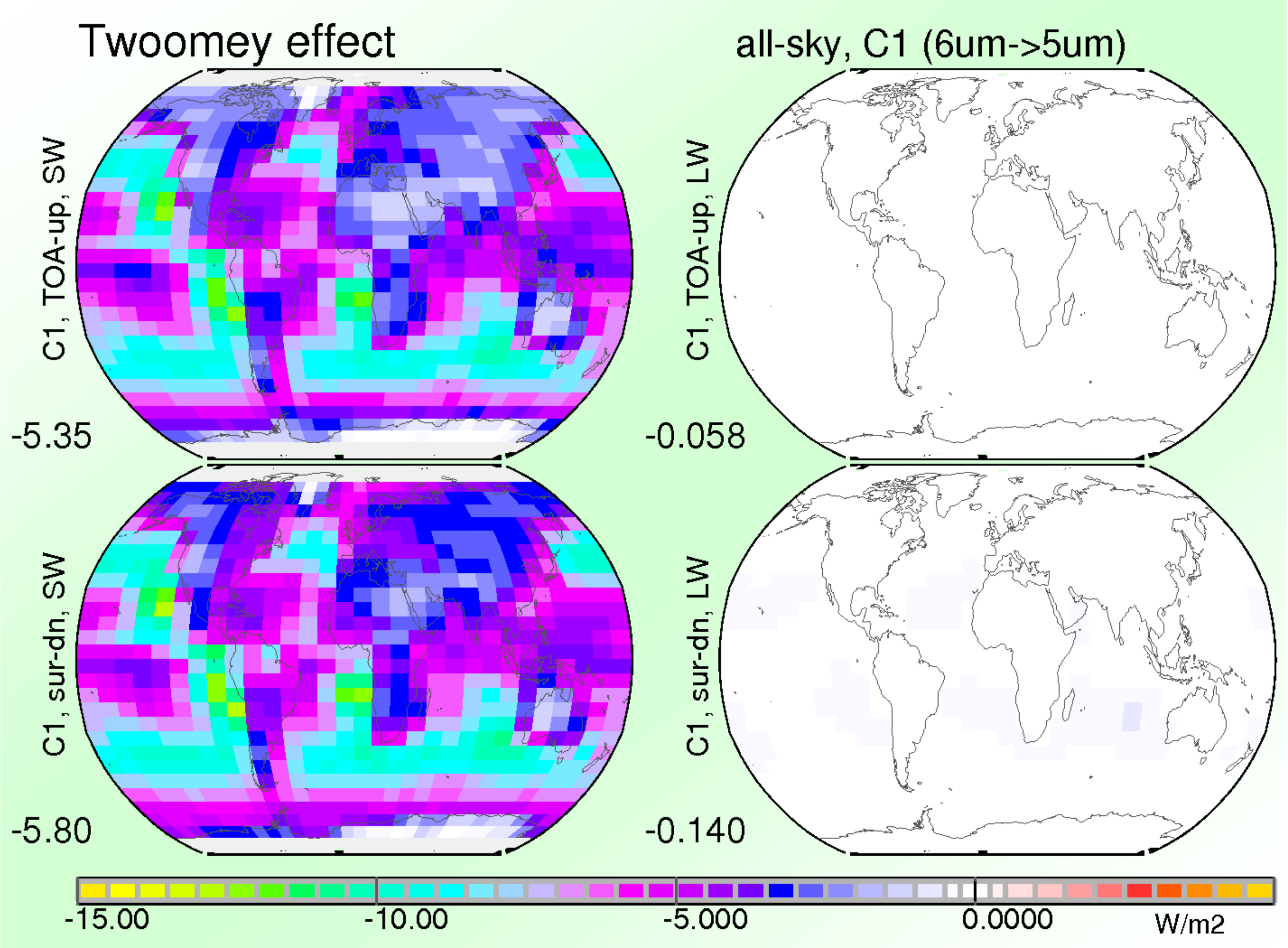
1.75 * more drops in a C5 cloud

no changes to liquid water in low clouds



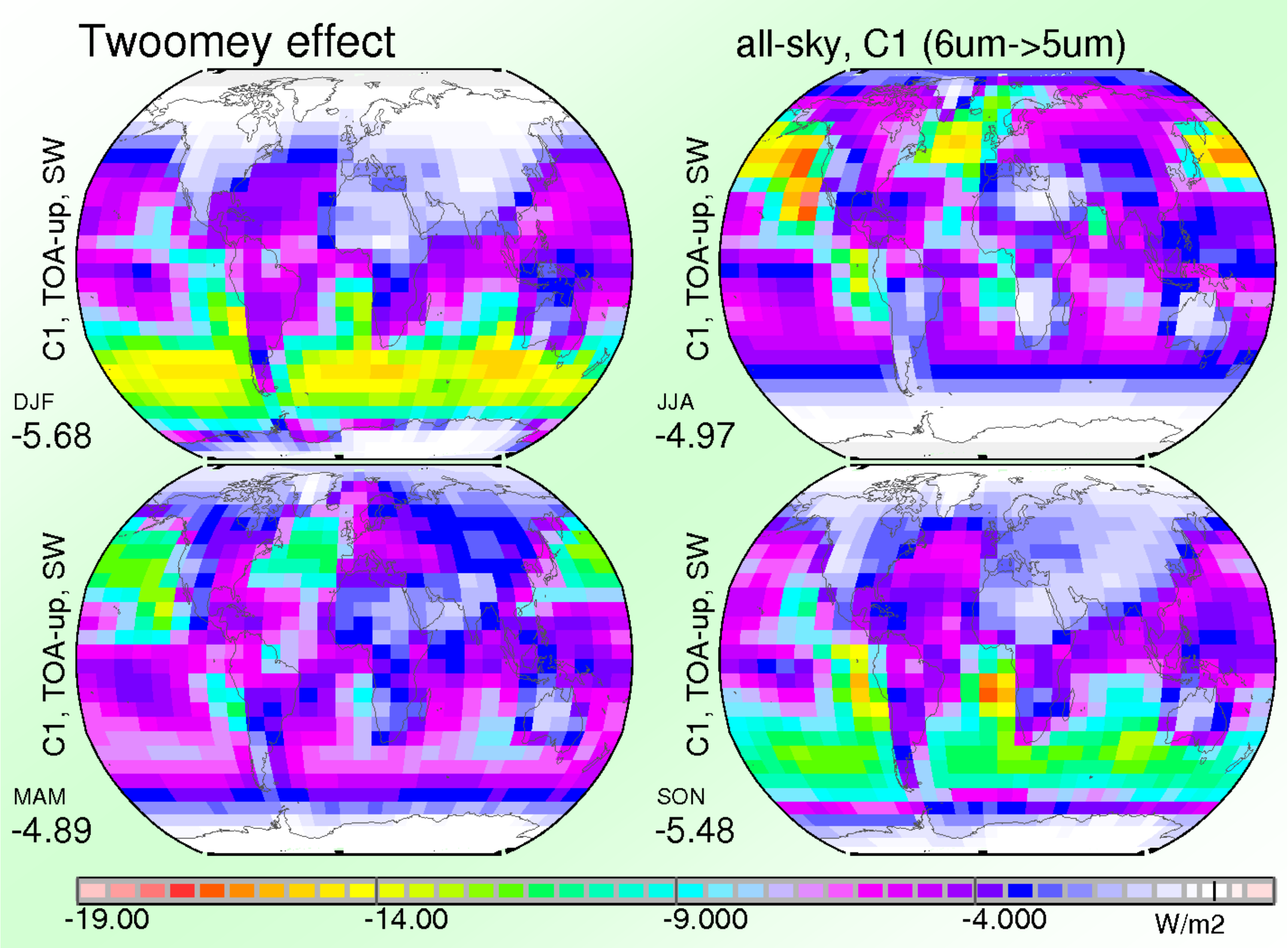
1.88* more drops in a C1 cloud

no changes to liquid water in low clouds



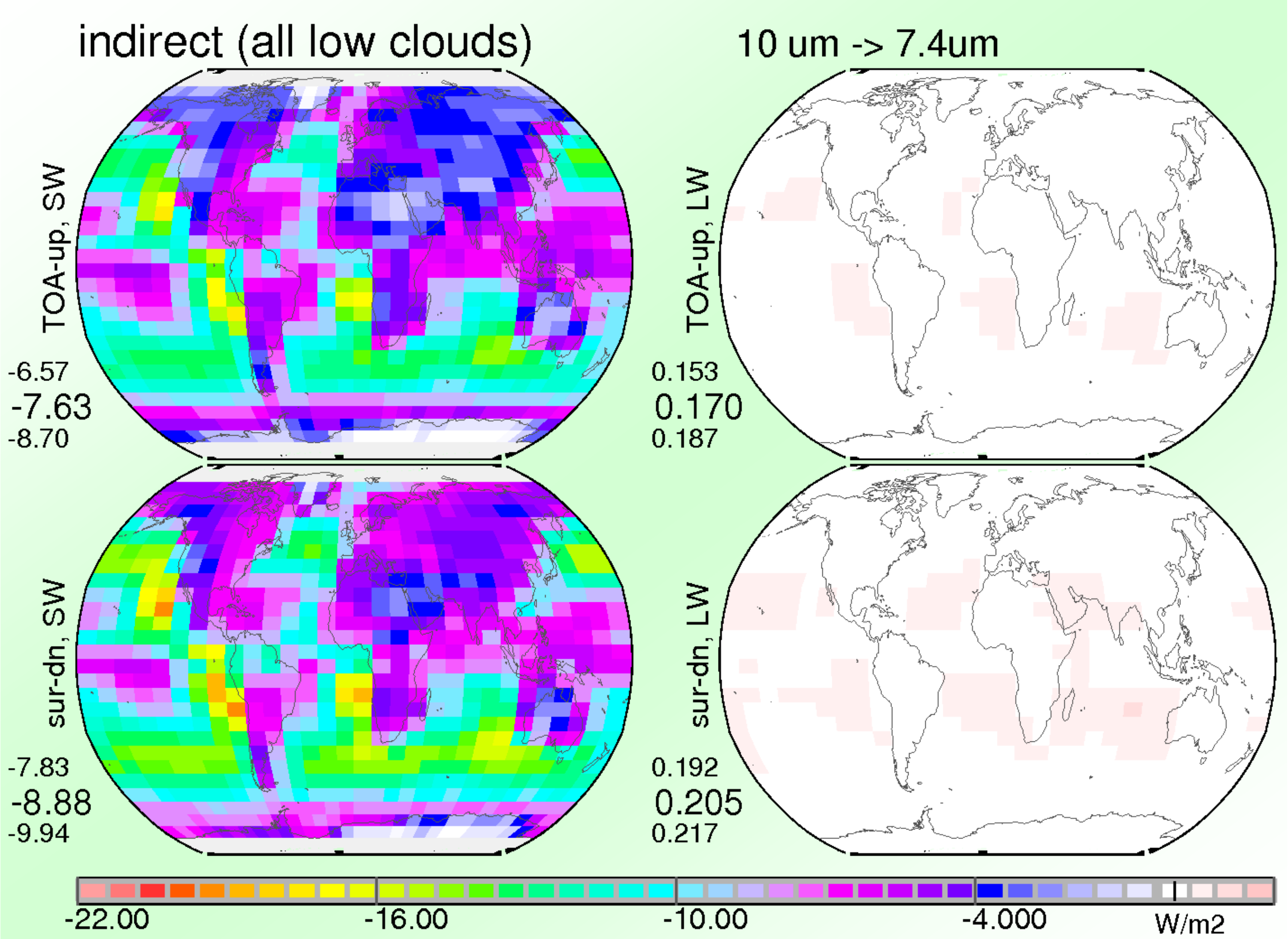
1.88* more drops in a C1 cloud

SW TOA effect by season



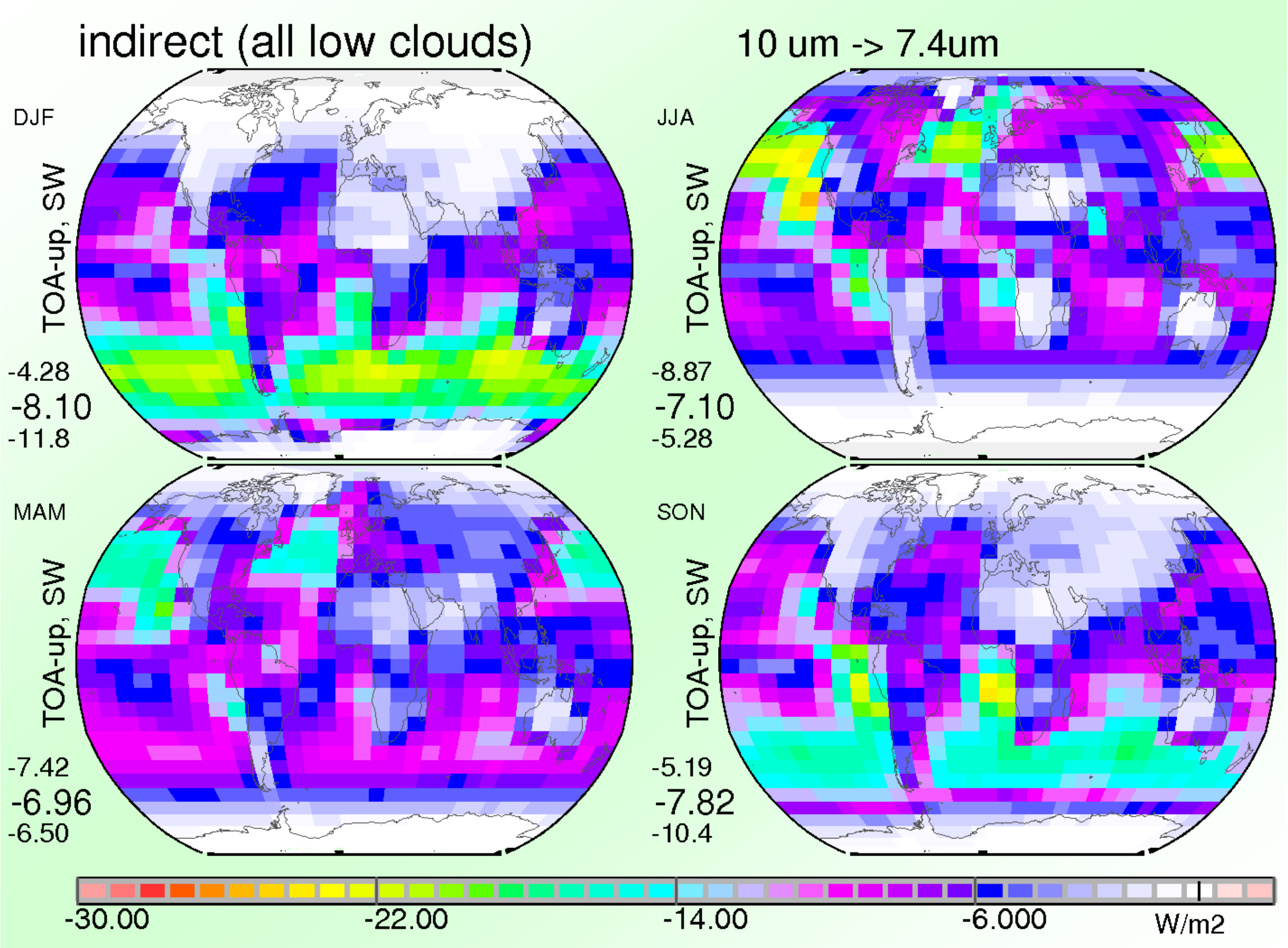
2.47* more drops in a ln cloud

no changes to liquid water in low clouds



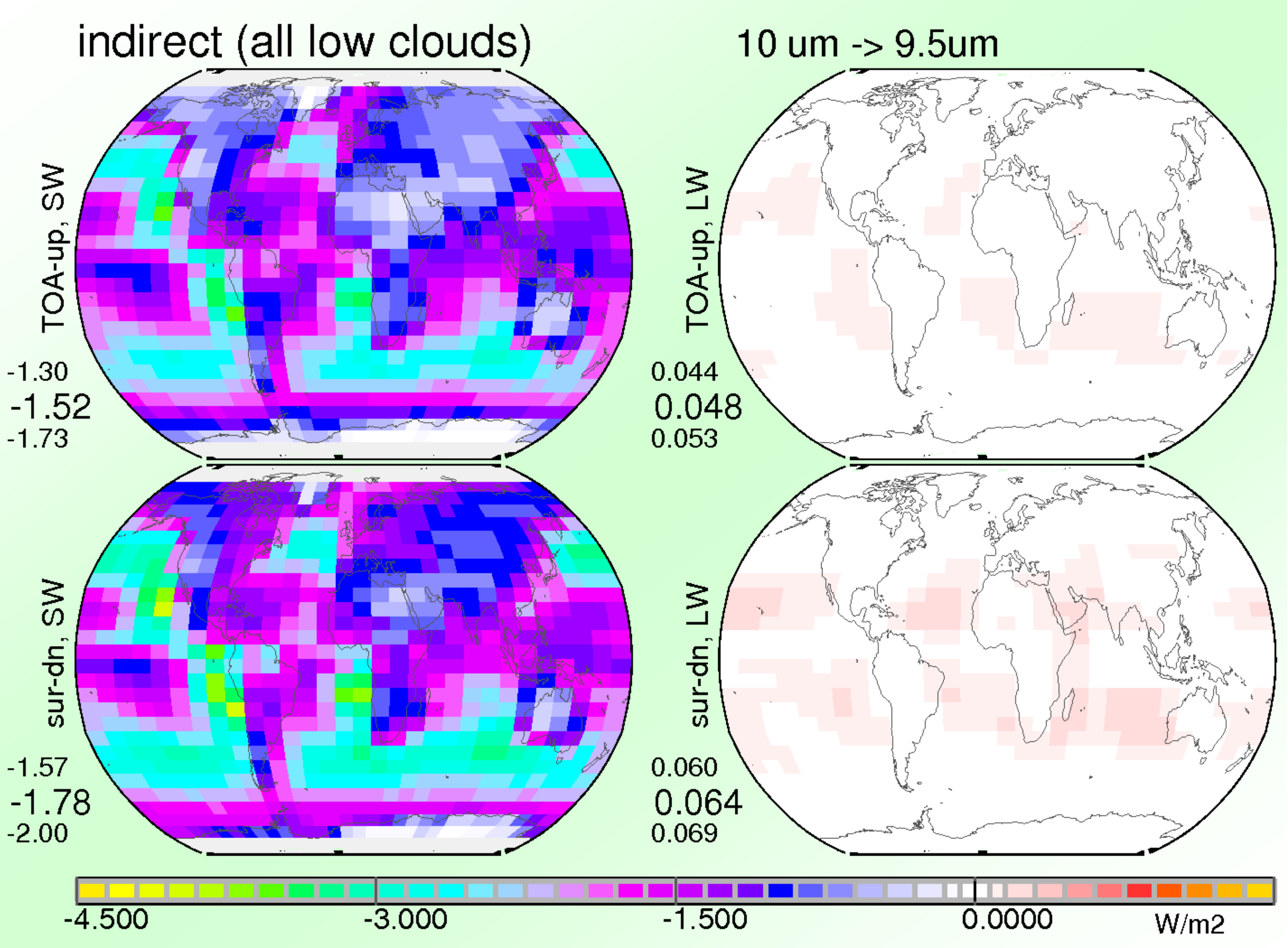
2.47* more drops in a ln cloud

SW TOA effect by season



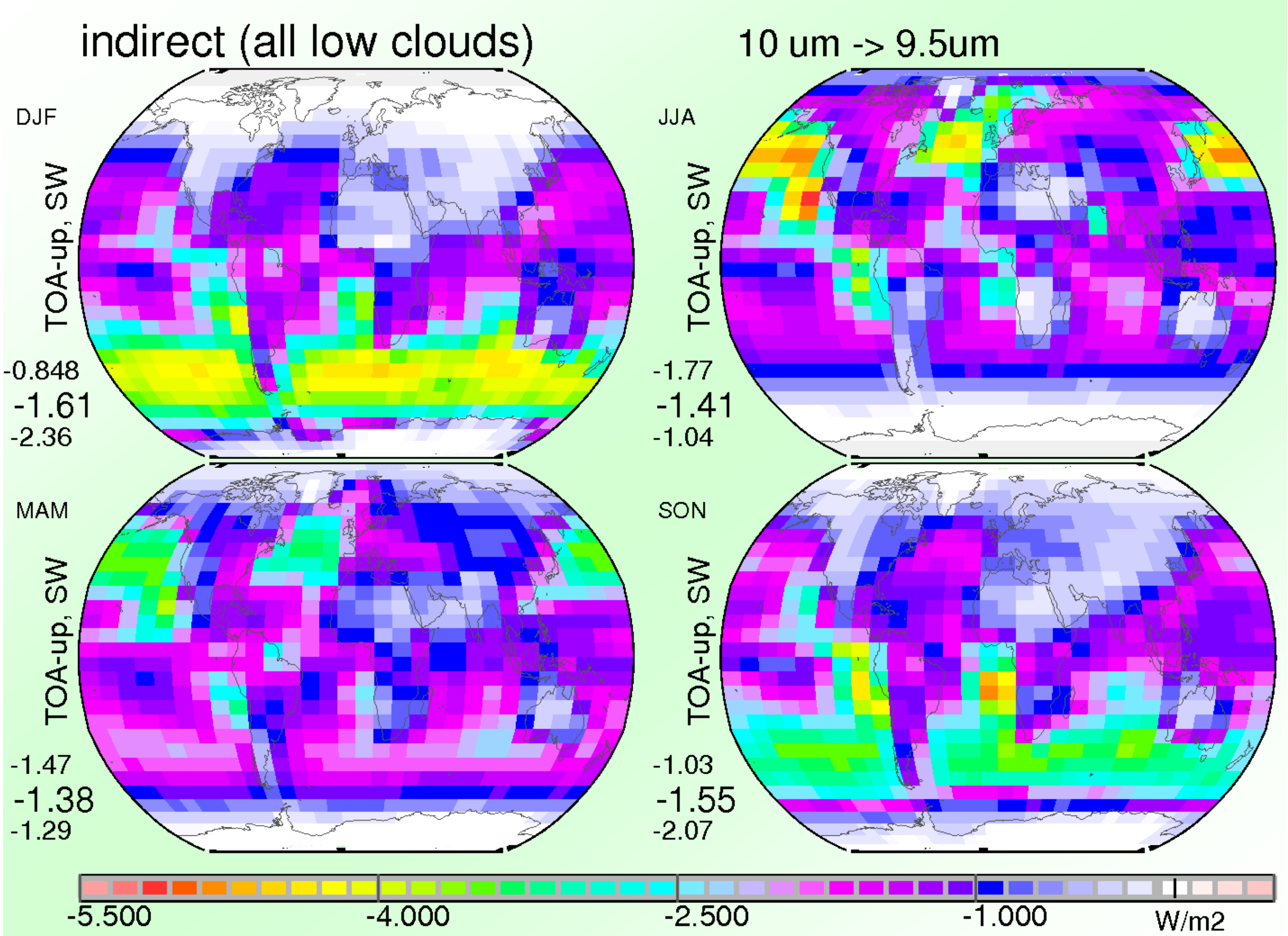
1.18* more drops in a ln cloud

no changes to liquid water in low clouds



1.18* more drops in a ln cloud

no changes to liquid water in low clouds

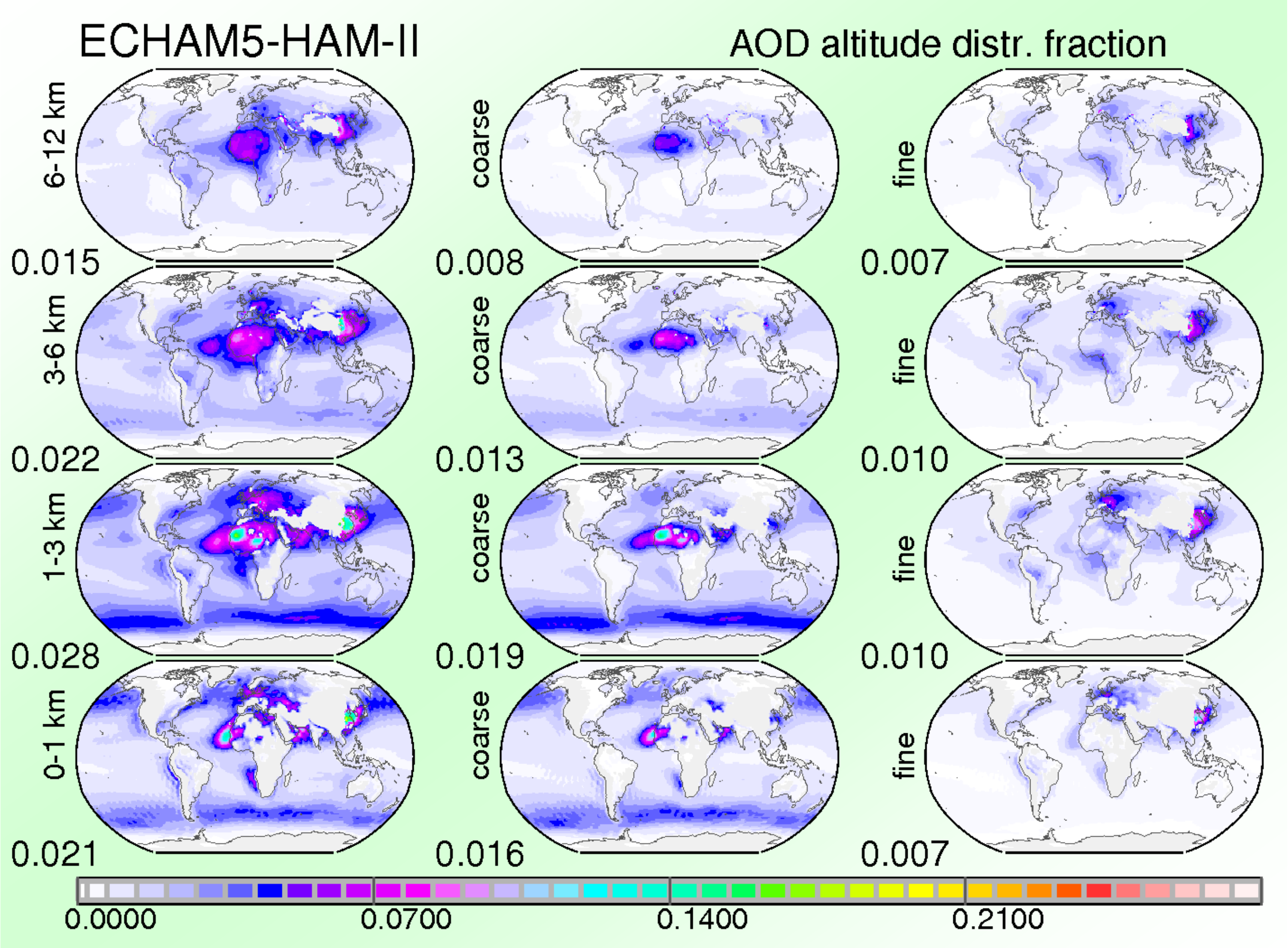


towards aerosol indirect forcing
using climatology predicted CCN concentrations

- quantifying CCN … requires
  - the vertical distribution (AOD → ext.)
  - the fine-mode size-distribution (ignore Aitken)
  - the aerosol composition (via 'kappa' hygro.)
  - the anthrop. fraction of the fine-mode
  - → critical radius (as function of SS)
  - – all sizes > critical radius (at base) become CCN
- all CCN activate as cloud droplet
  - CCN # at cloud base are applied to low cloud
  - droplet radii are reduced by CCN # increase
  - no changes to cloud liq.water content allowed

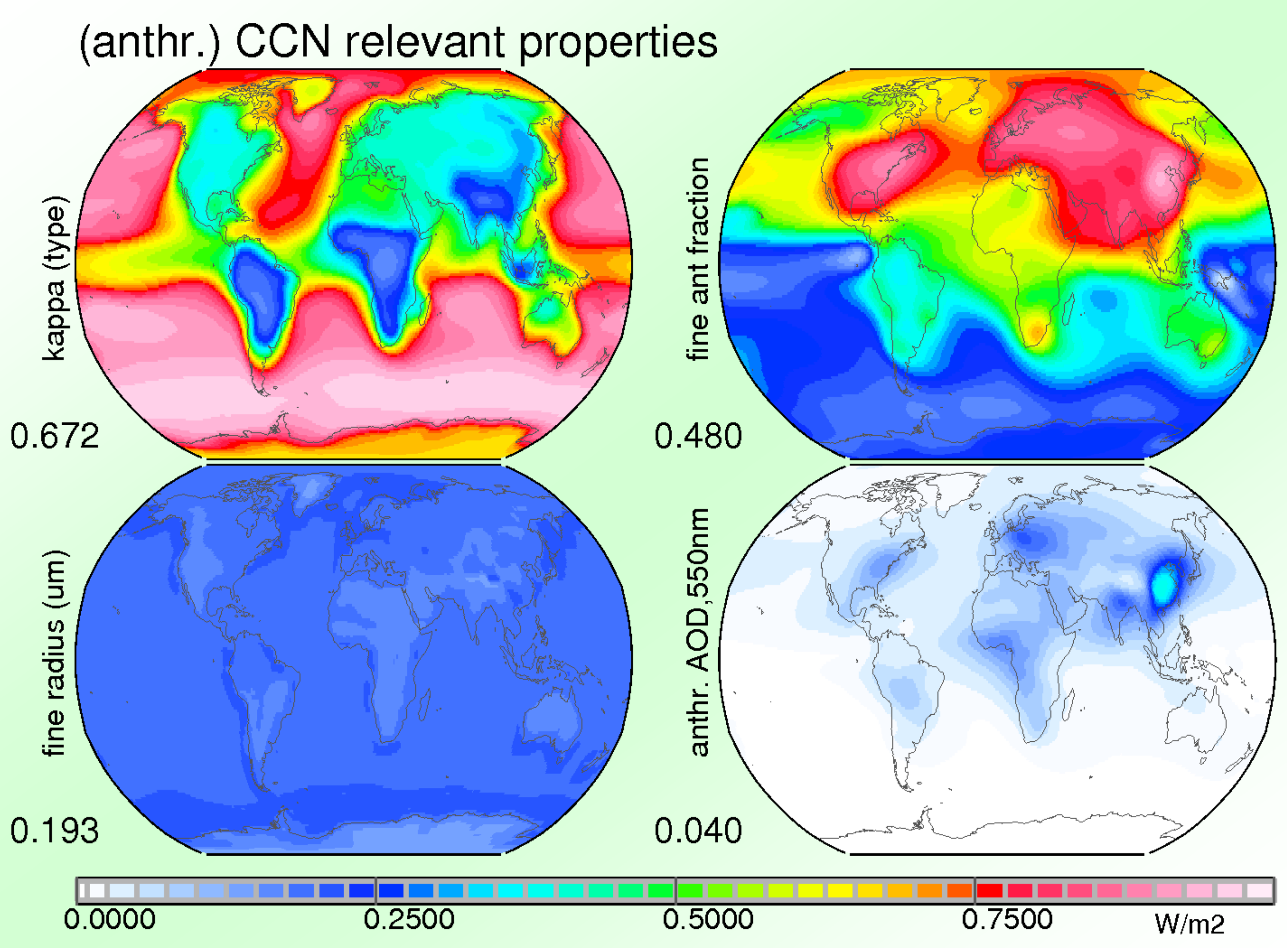
CCN / IN are concentrations

applied information on AOD vertical distribution



other important ingredients

kappa →size , anthrop. fraction in fine-mode



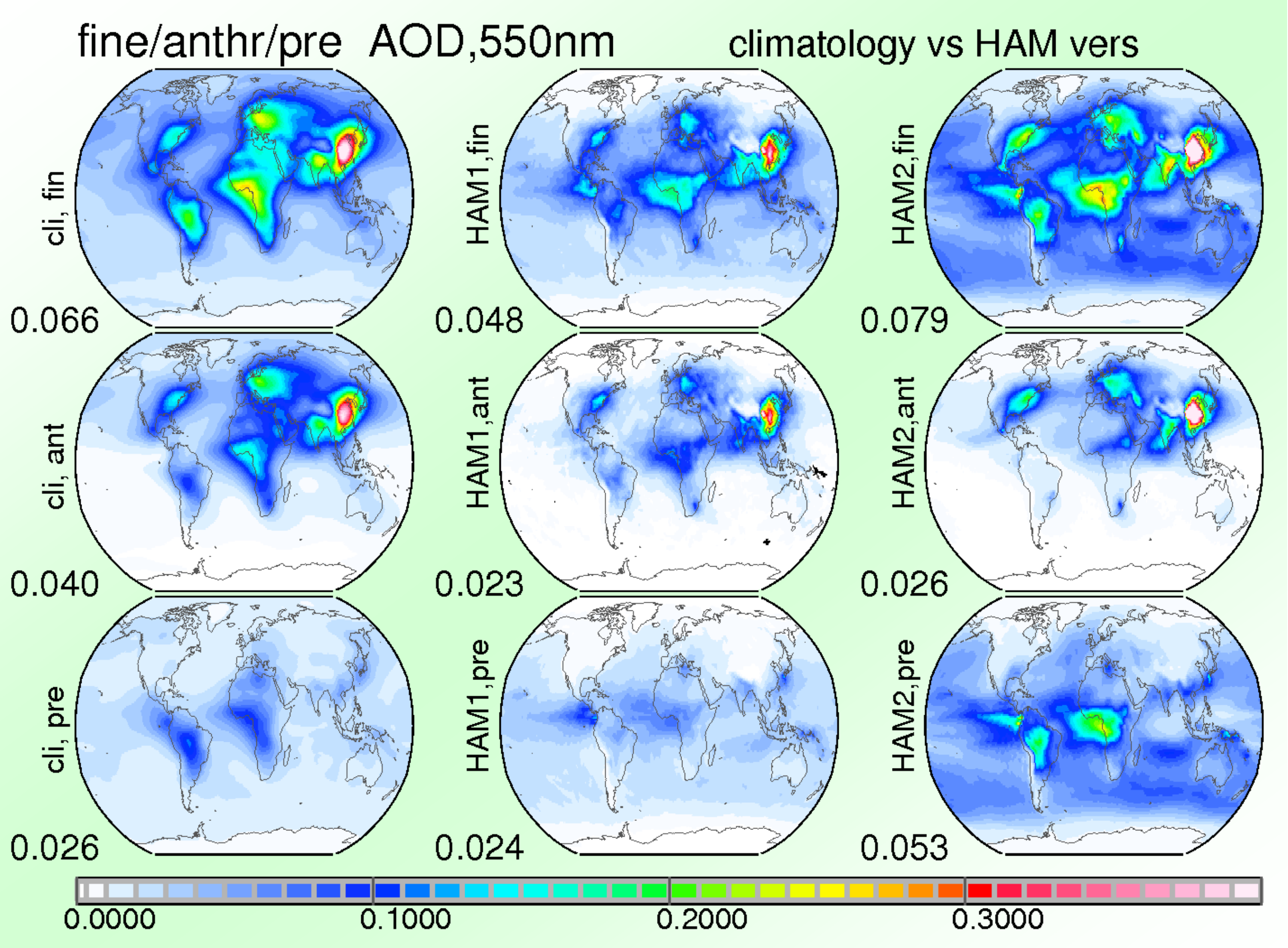
anthrop ? ← depends on pre-industrial
3 models … three suggestions

fine-mode AOD

anthropog. AOD

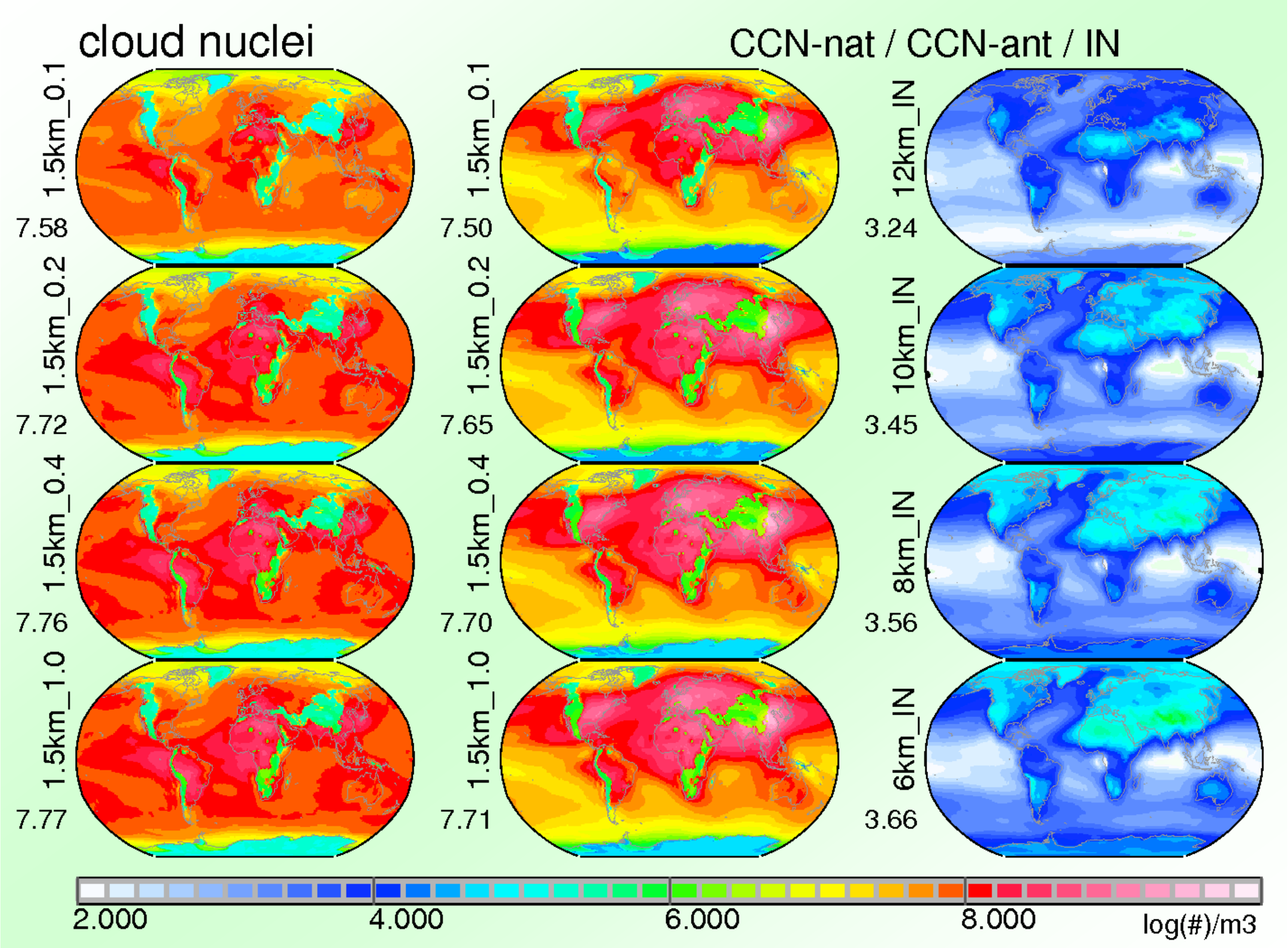
pre-industrial AOD

what AOD was there to begin with ?



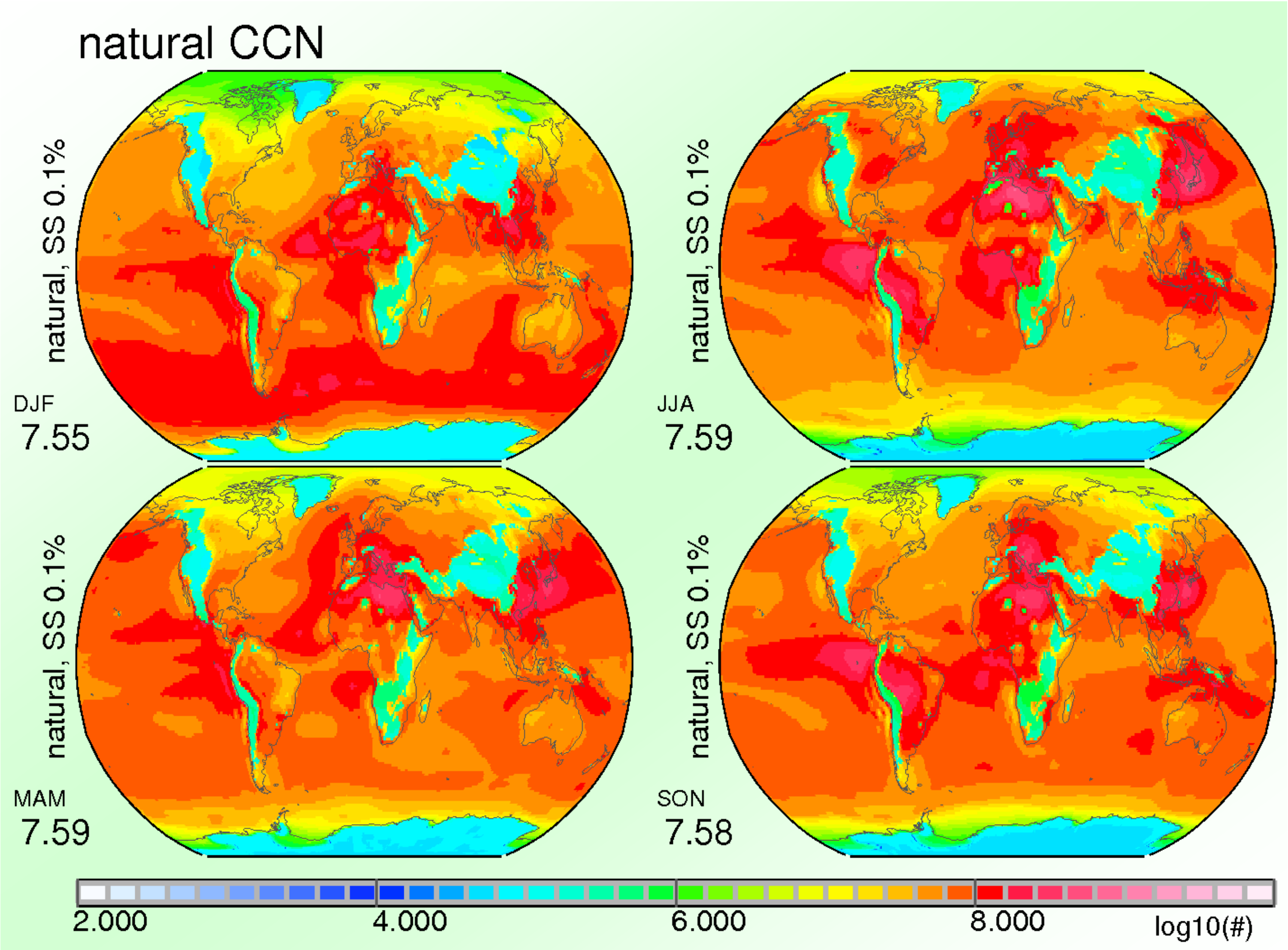
CCN / IN concentrations (log10 scale)

for different supersaturations and altitudes



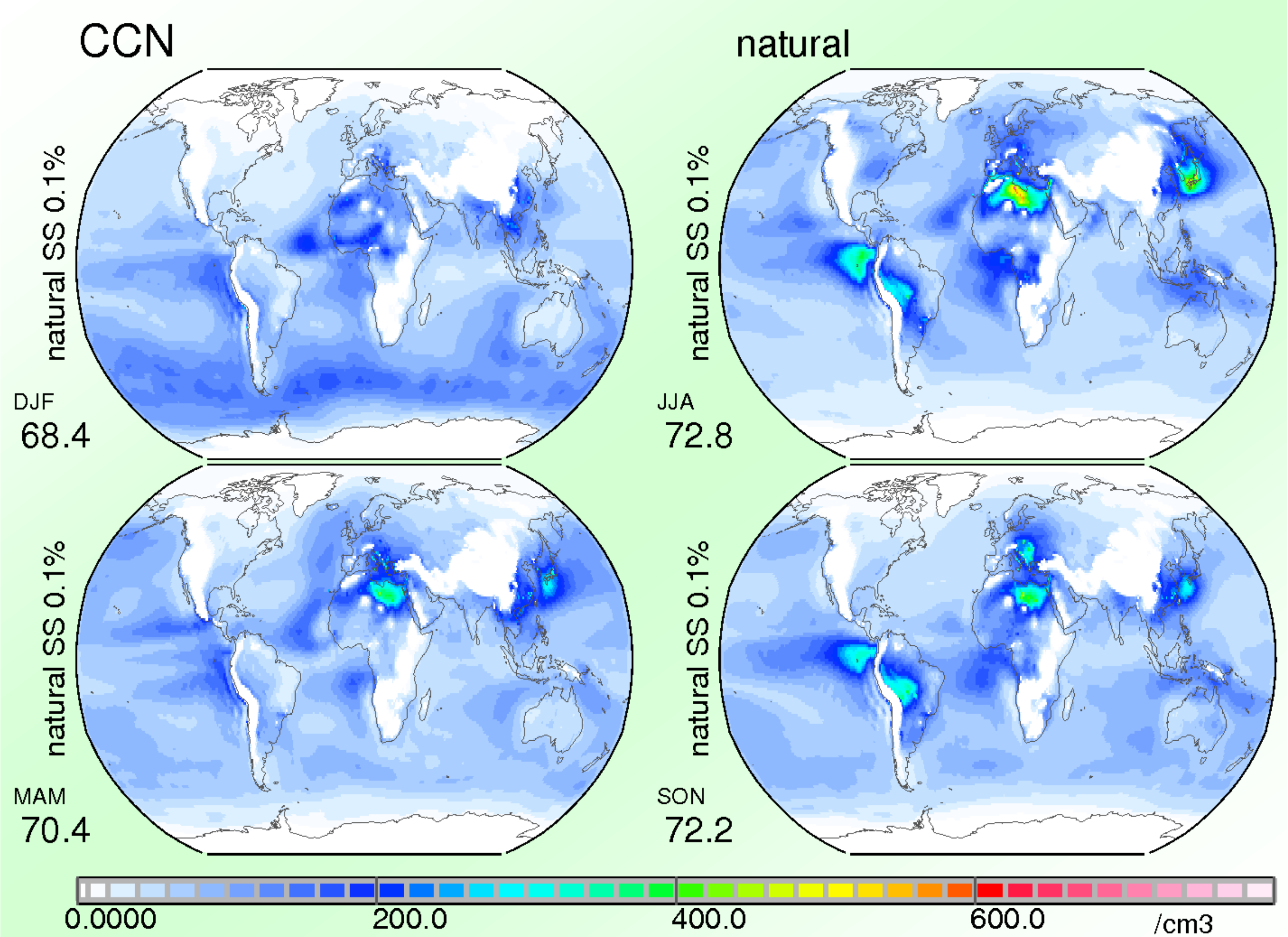
natural CCN (log10 scale)

at low altitude cloud base



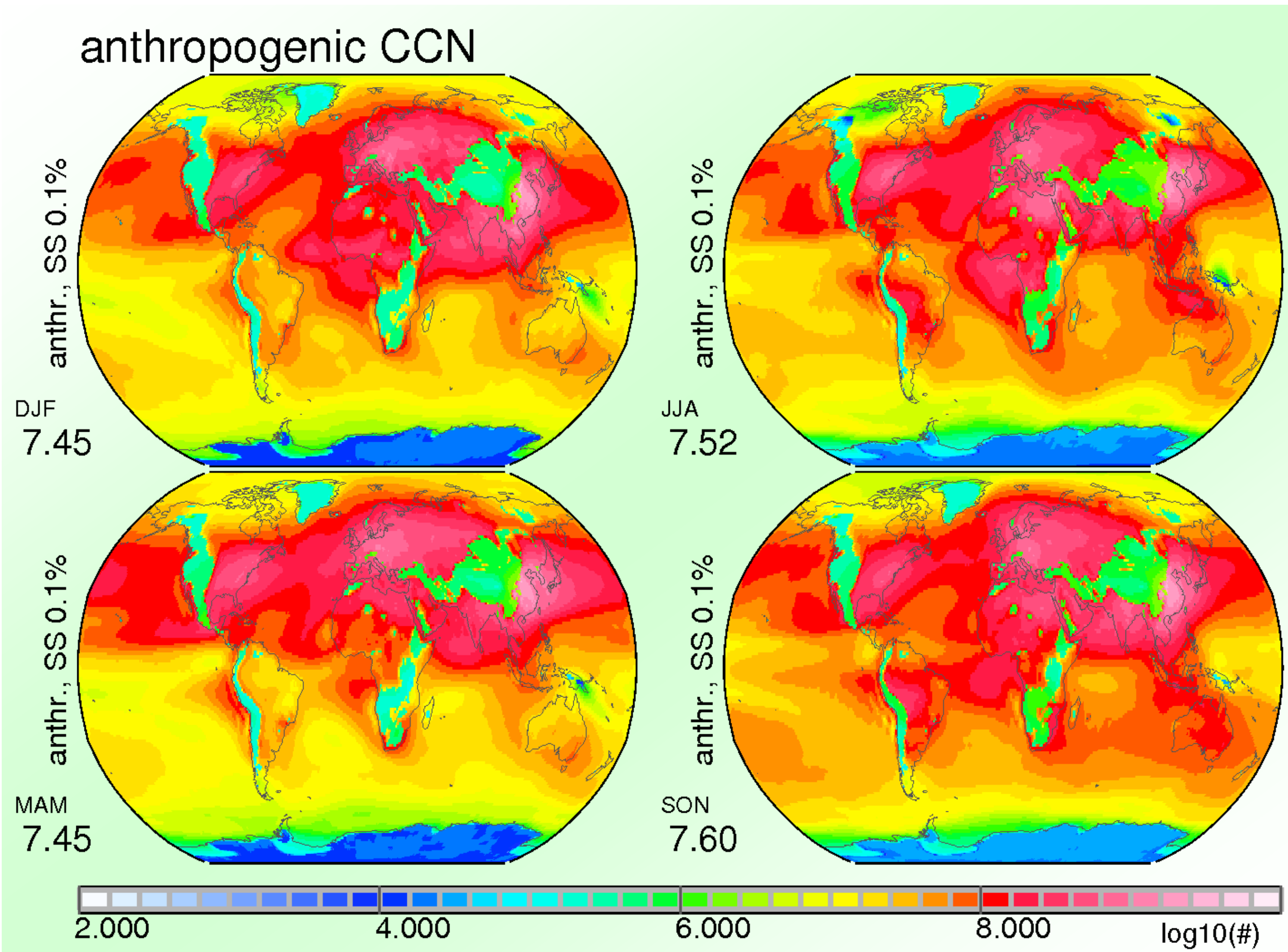
natural CCN

at low altitude cloud base



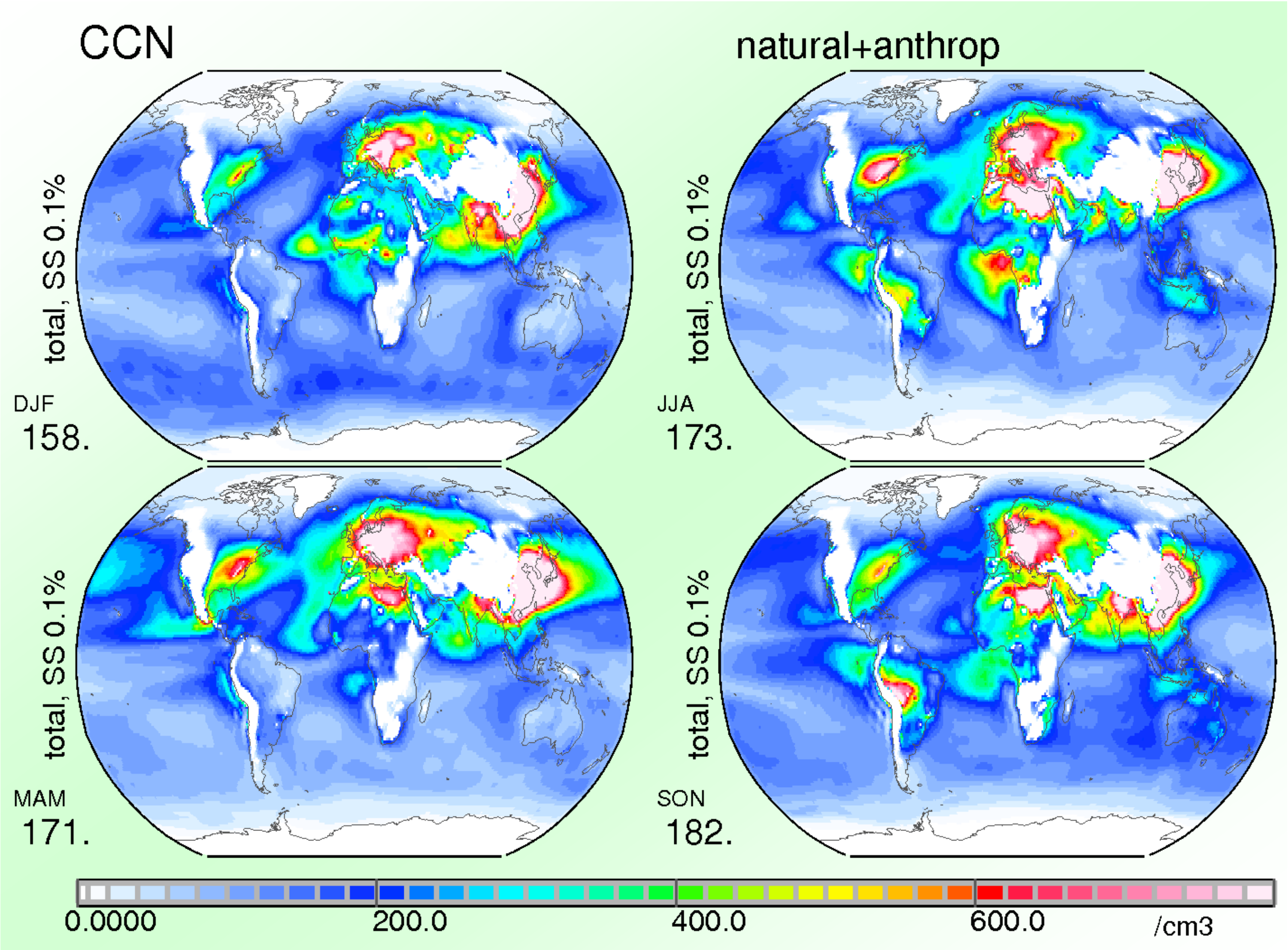
anthropogenic CCN (log10 scale)

at low altitude cloud base



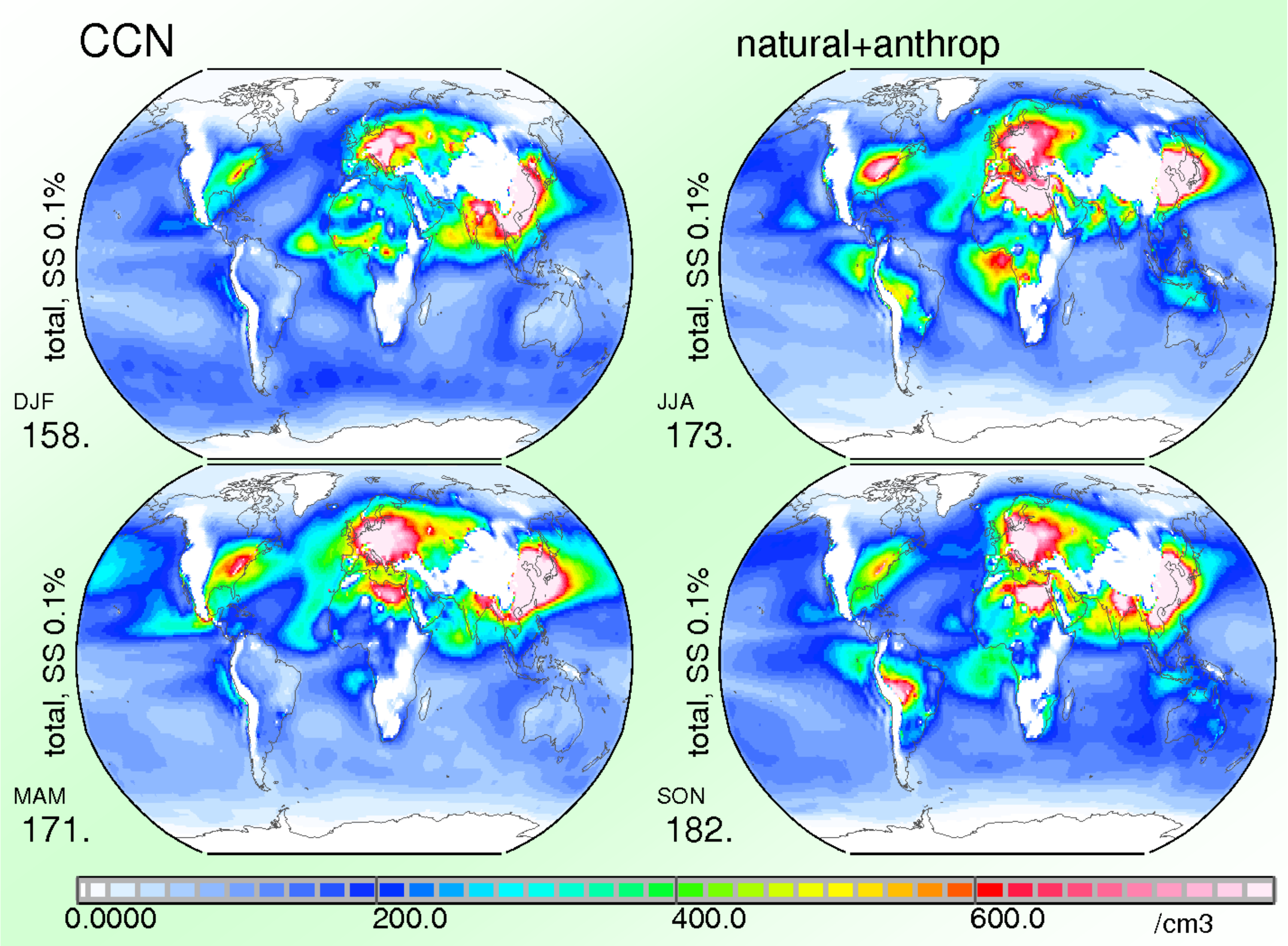
anthropogenic CCN

at low altitude cloud base (max e



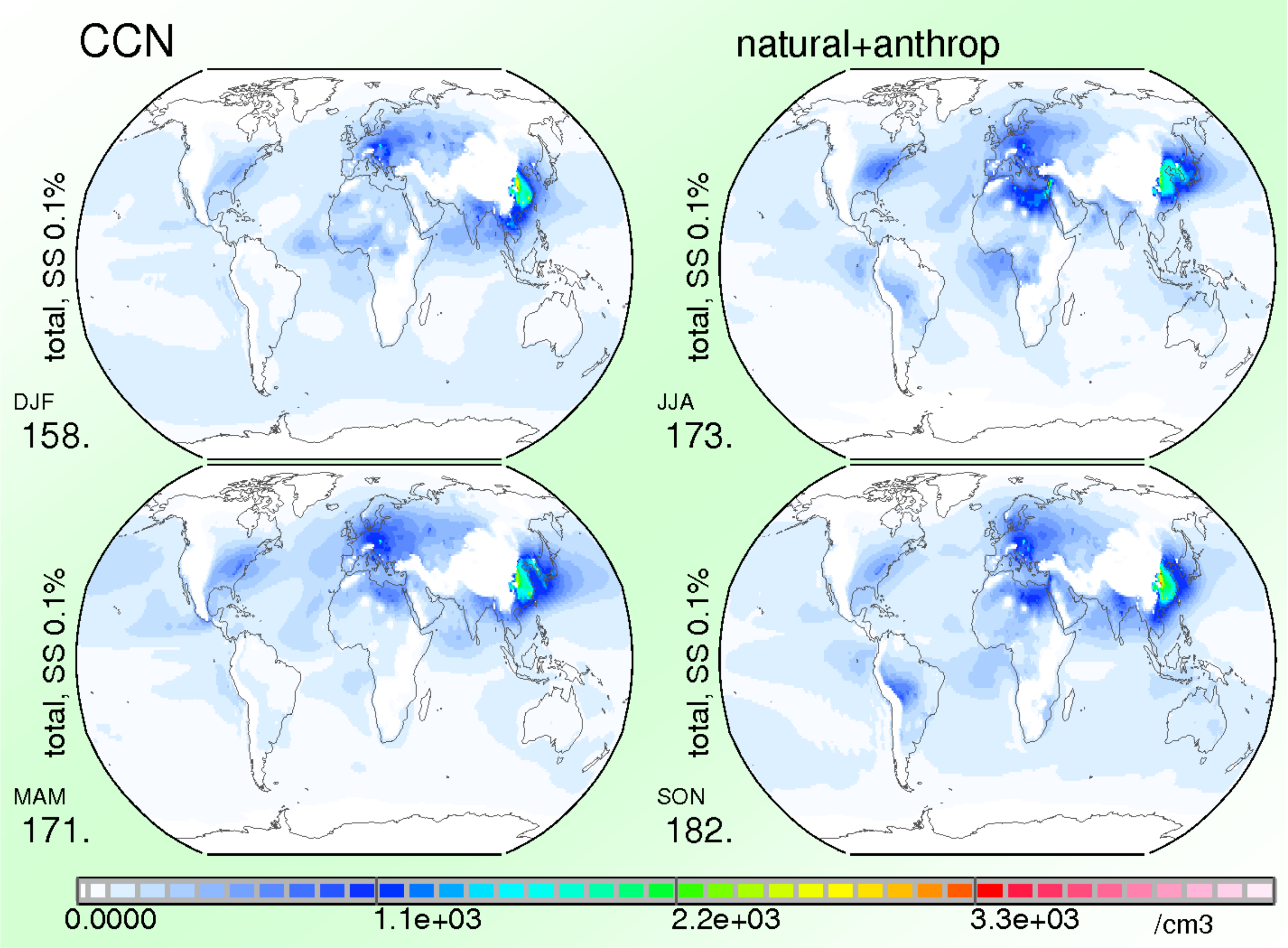
anthropogenic CCN

at low altitude cloud base (max set to 800/cm3)



anthropogenic CCN

at low altitude cloud base (max set to 800/cm3)



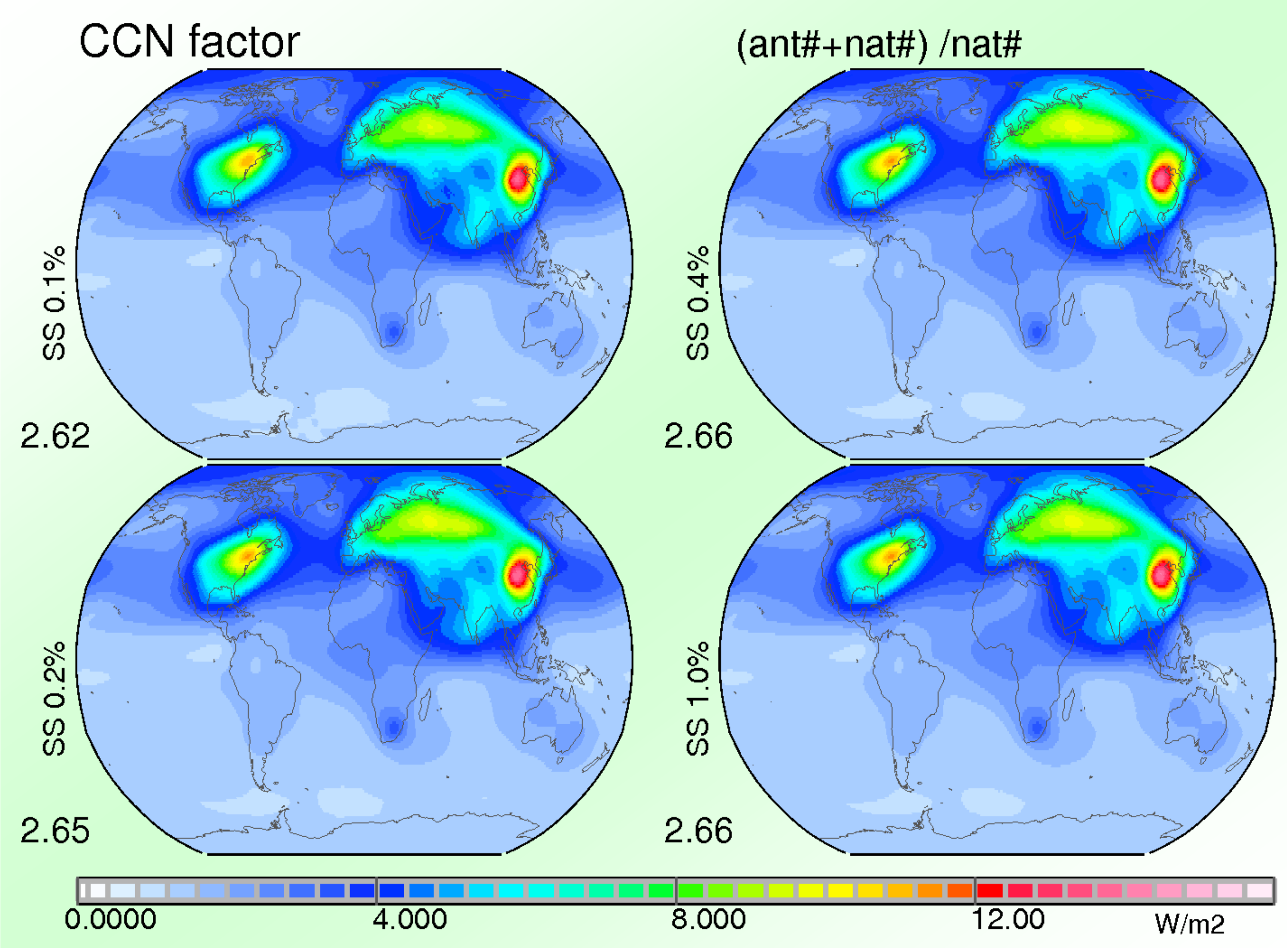
1. experiment

- assume that ALL extra anthropogenic CCN … become new cloud droplets

- new CCN = old CCN * ratio
    - ratio = (ant CCN +nat CCN) / (nat CCN)

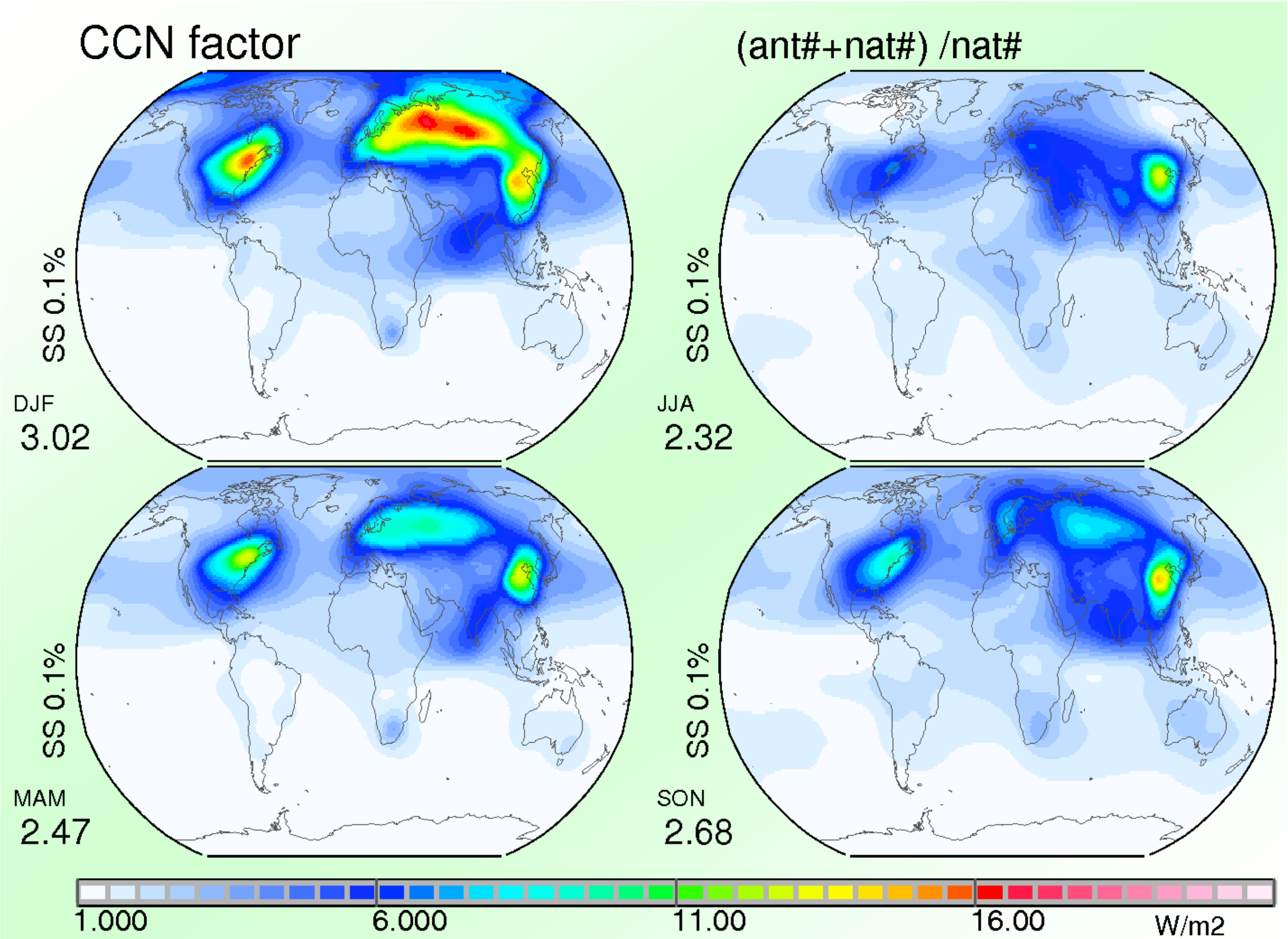
(ant$_{CCN}$+nat$_{CCN}$) / nat$_{CCN}$ - ratios

ratio is largely independent on supersaturation



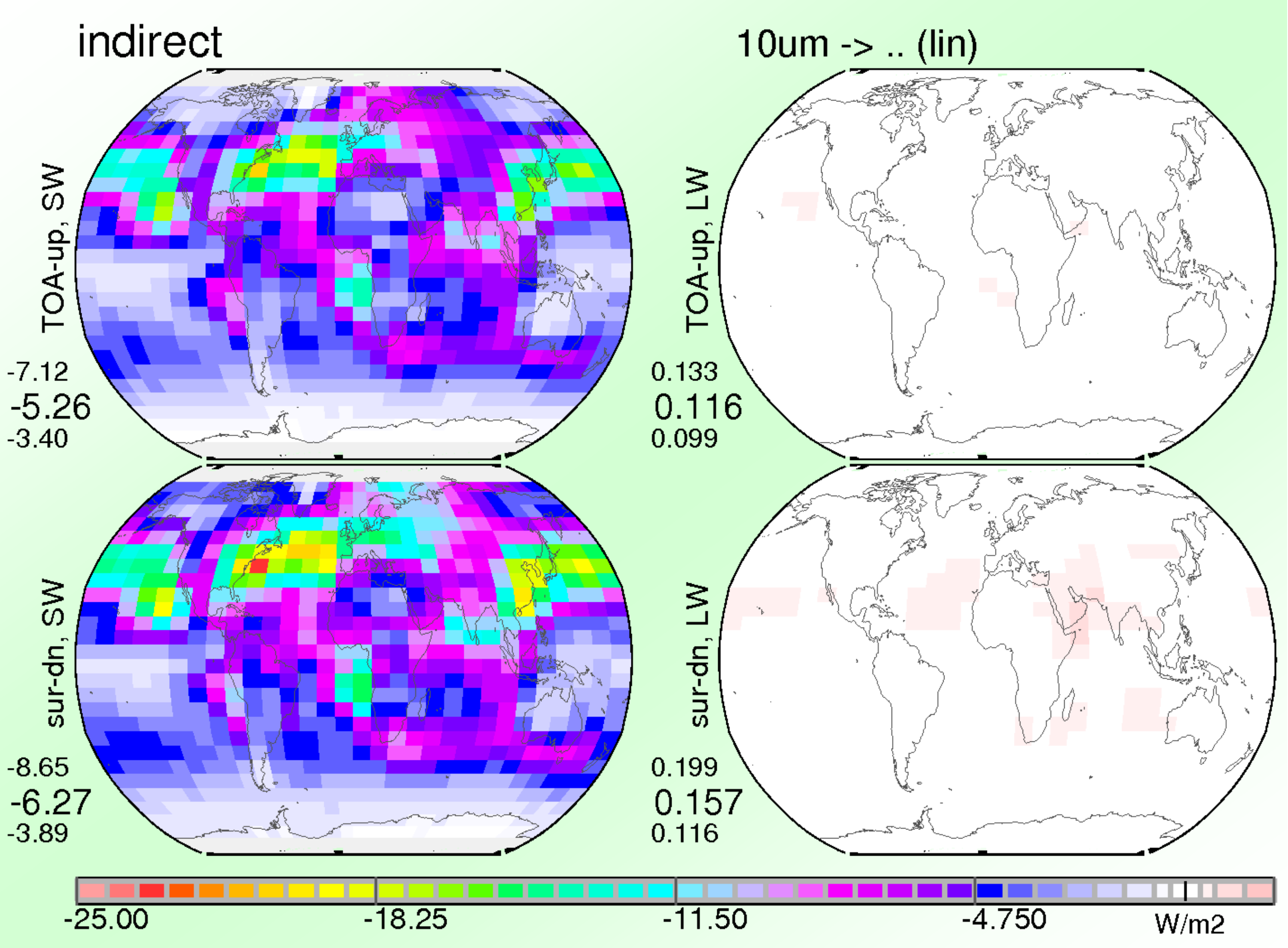
(antCCN+natCCN) / natCCN - ratios

for 0.1% super-saturation, seasonal



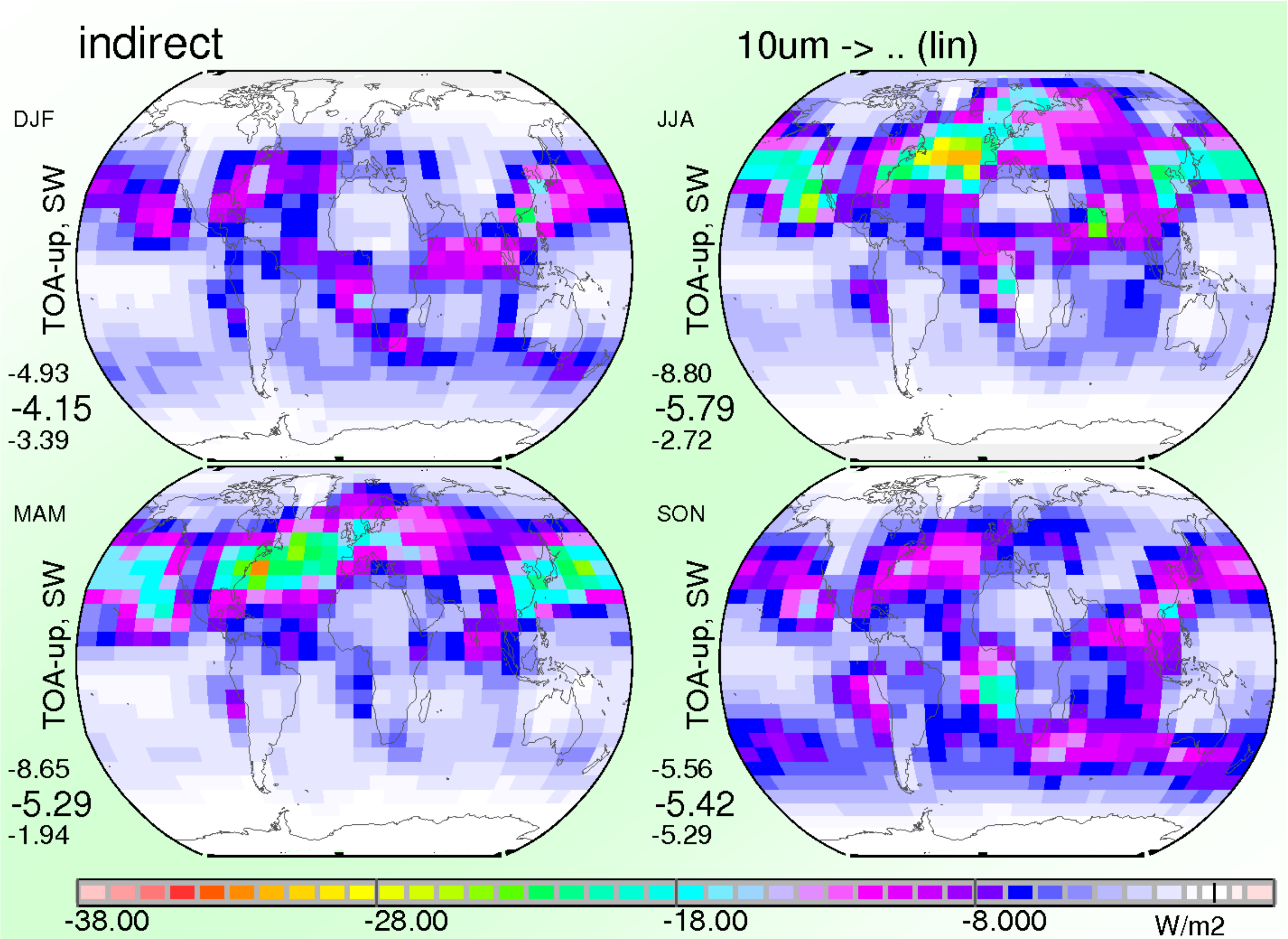
aerosol low cloud indirect effects

liquid water remains constant



SW cloud effect: - 5.6 W/m2

seasonal variations



2. experiment

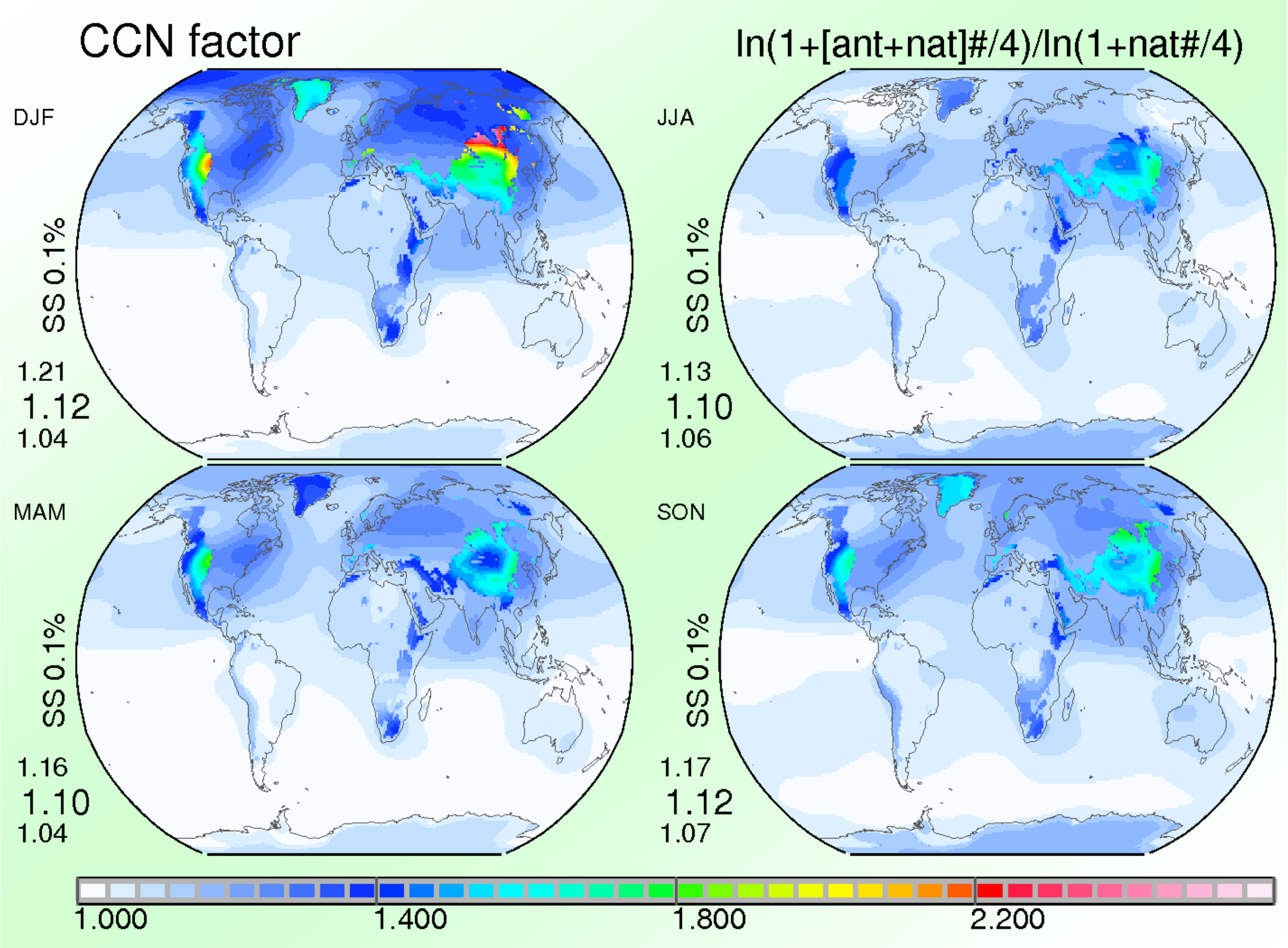
- assume the following CCN to drop conversion
  - ALL CCN become new cloud droplets
    - if CCN concentrations are low
  - a fraction of CCN becomes new cloud droplets
    - if CCN concentrations are high

- new CCN = old CCN * ratio
    - ratio = ln (1 + [ant CCN +nat CCN]/ 10**4) / ln (1 + [nat CCN] / 10**4)

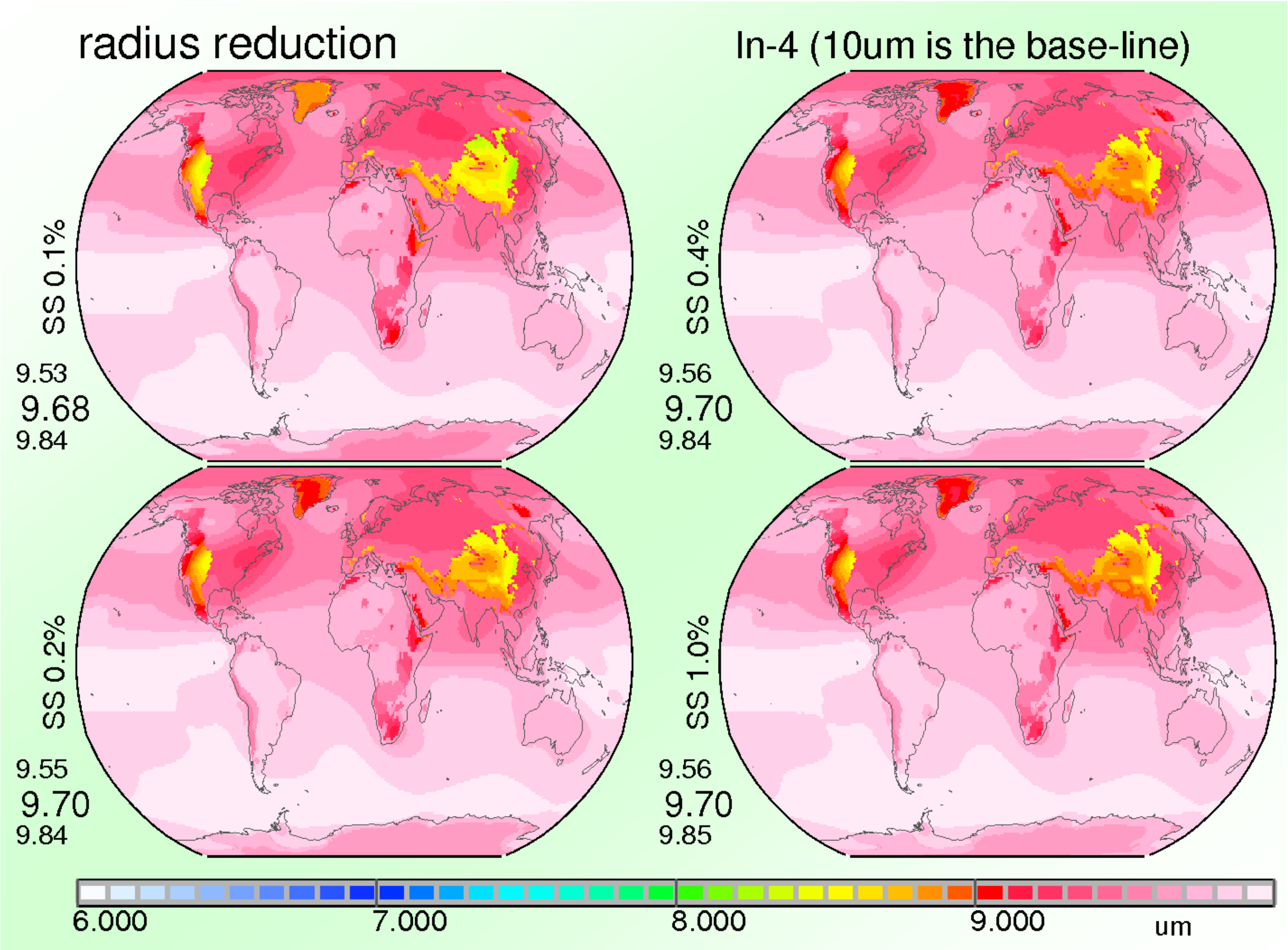
CCN in # /m3

ln(1+ant+nat) / ln(1+nat) - ratios

with CCN values (/m) divided by 10000

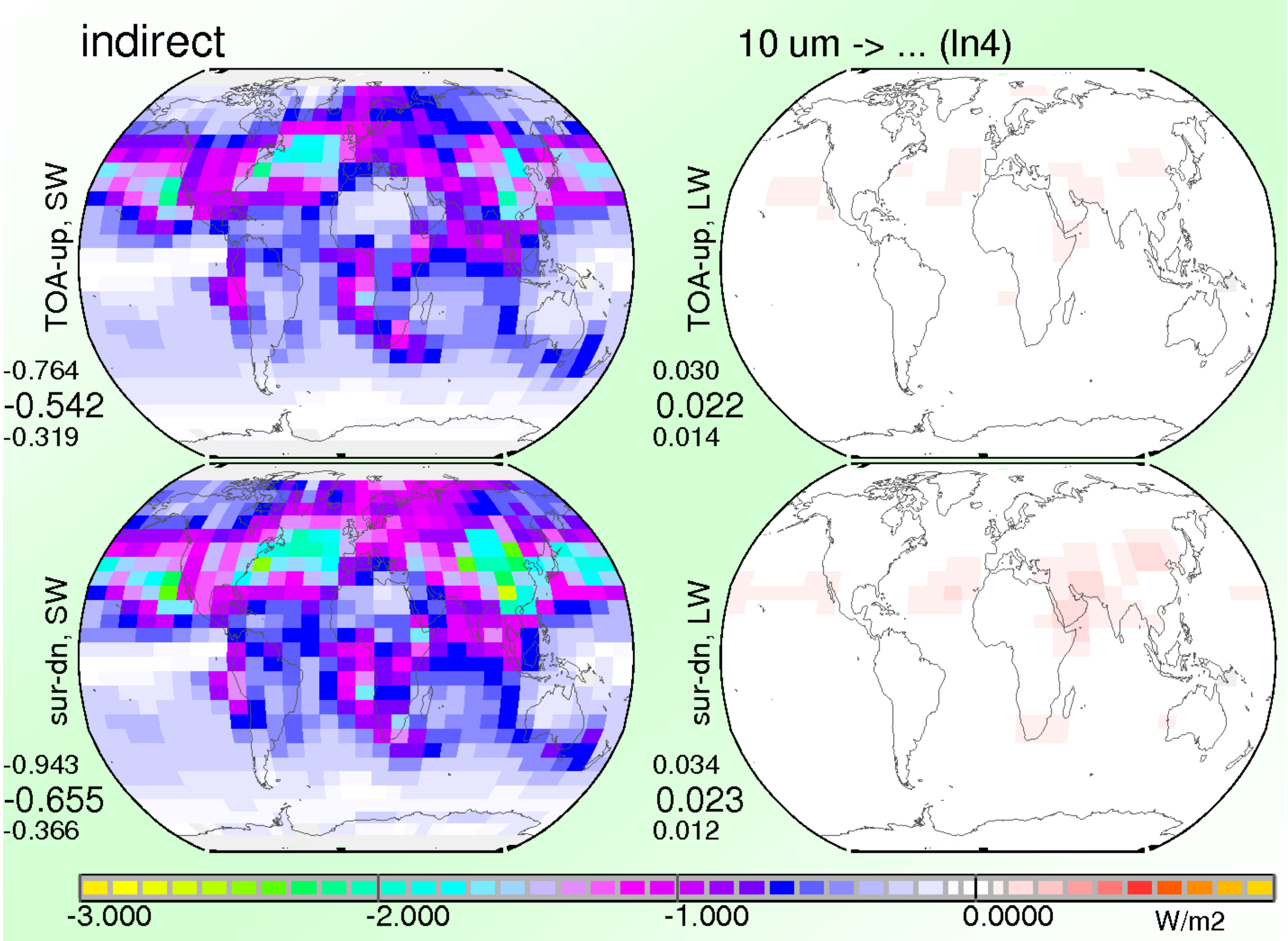


cloud drop size reductions



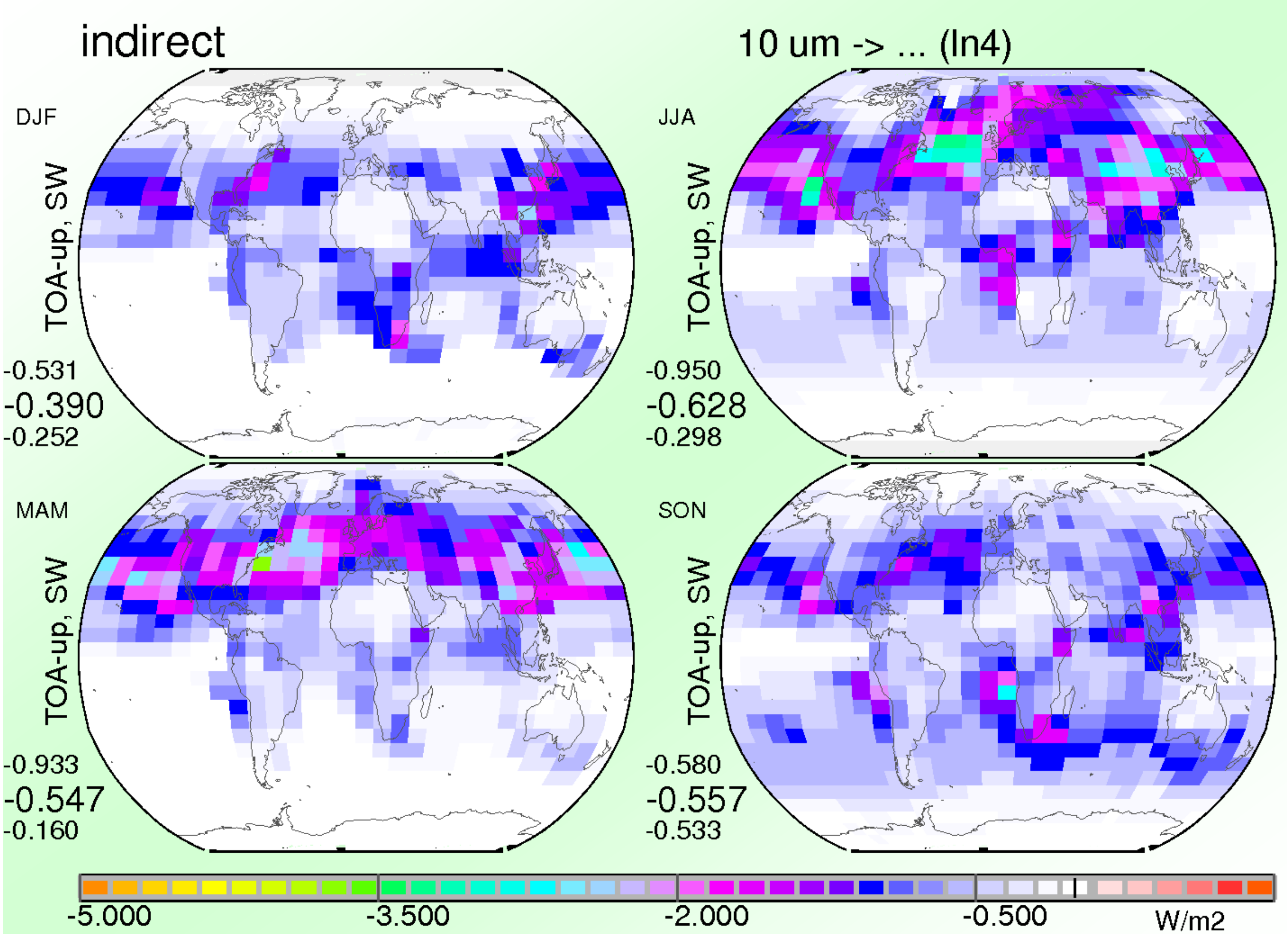
aerosol low cloud indirect effects

liquid water remains constant



aerosol low cloud indirect effects

liquid water remains constant



3. experiment (best estimate)

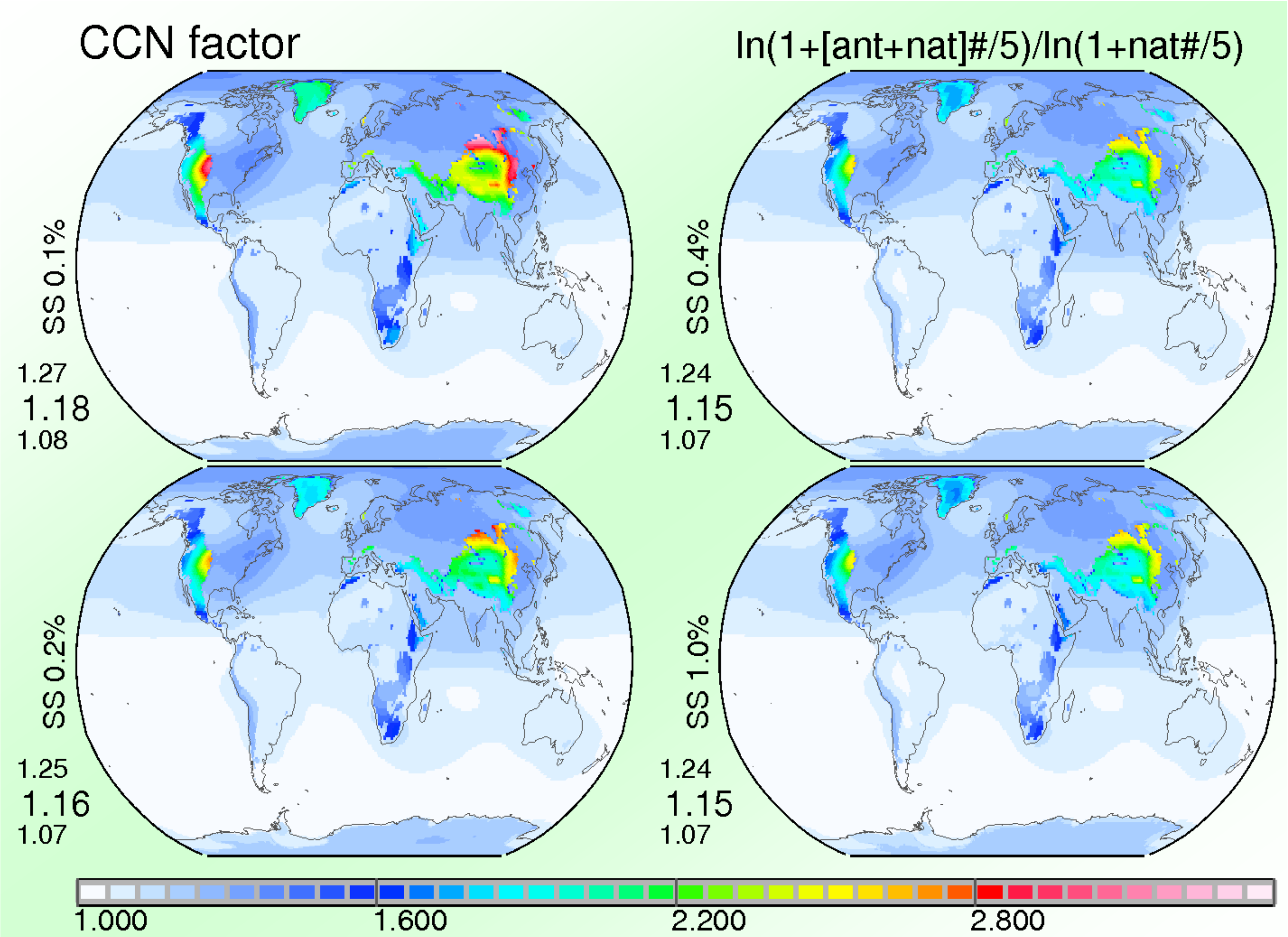
- assume the following CCN to drop conversion
  - – ALL CCN become new cloud droplets
    - if CCN concentrations are low
  - – a fraction of CCN becomes new cloud droplets
    - if CCN concentrations are high

- new CCN = old CCN * ratio
  - ratio = ln (1 + [ant CCN +nat CCN]/ 10**5)
    / ln (1 + [nat CCN] / 10**5)

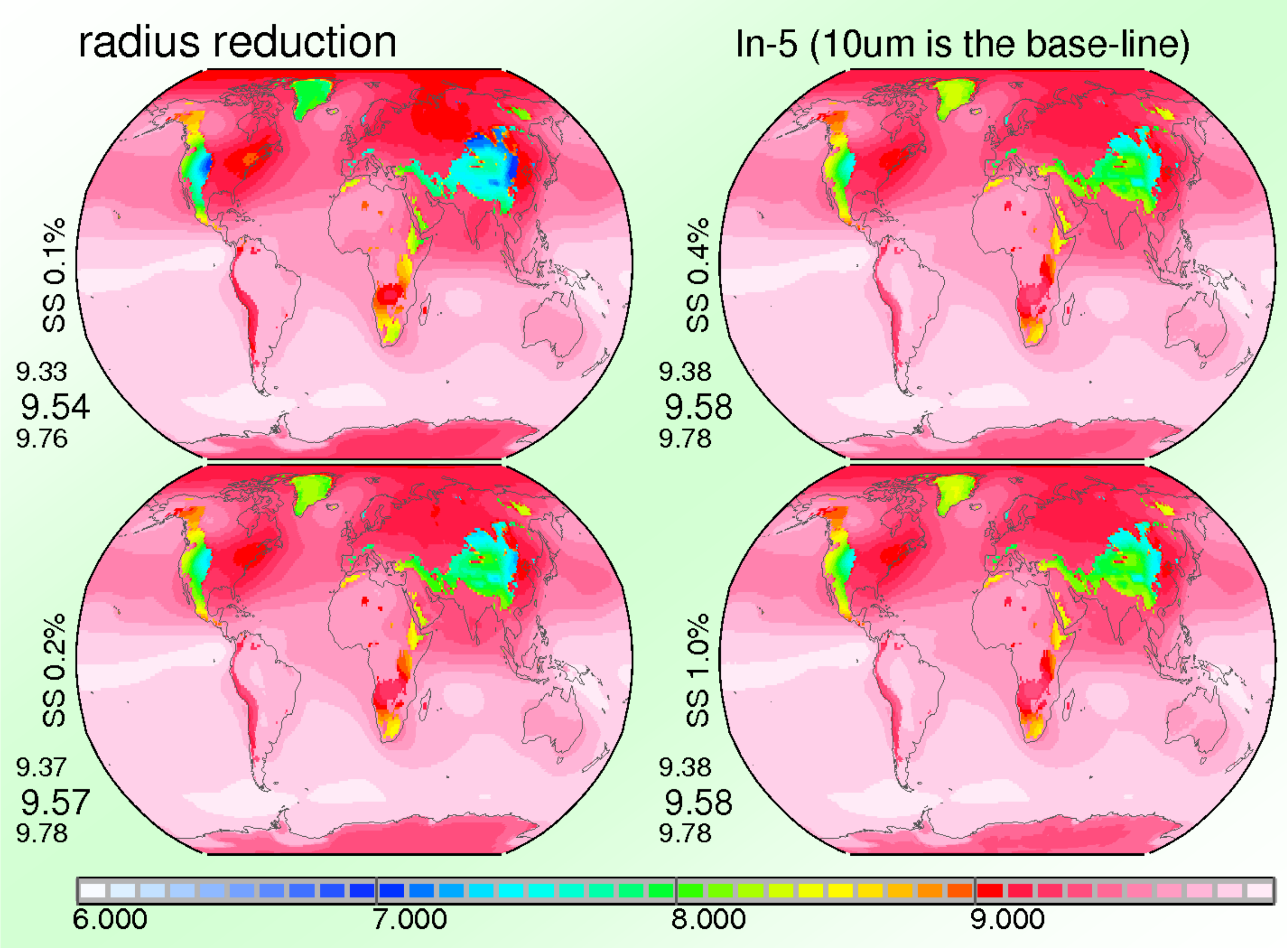
CCN in # /m3

ln(1+ant+nat) / ln(1+nat) - ratios

with CCN values (/m) divided by 100000

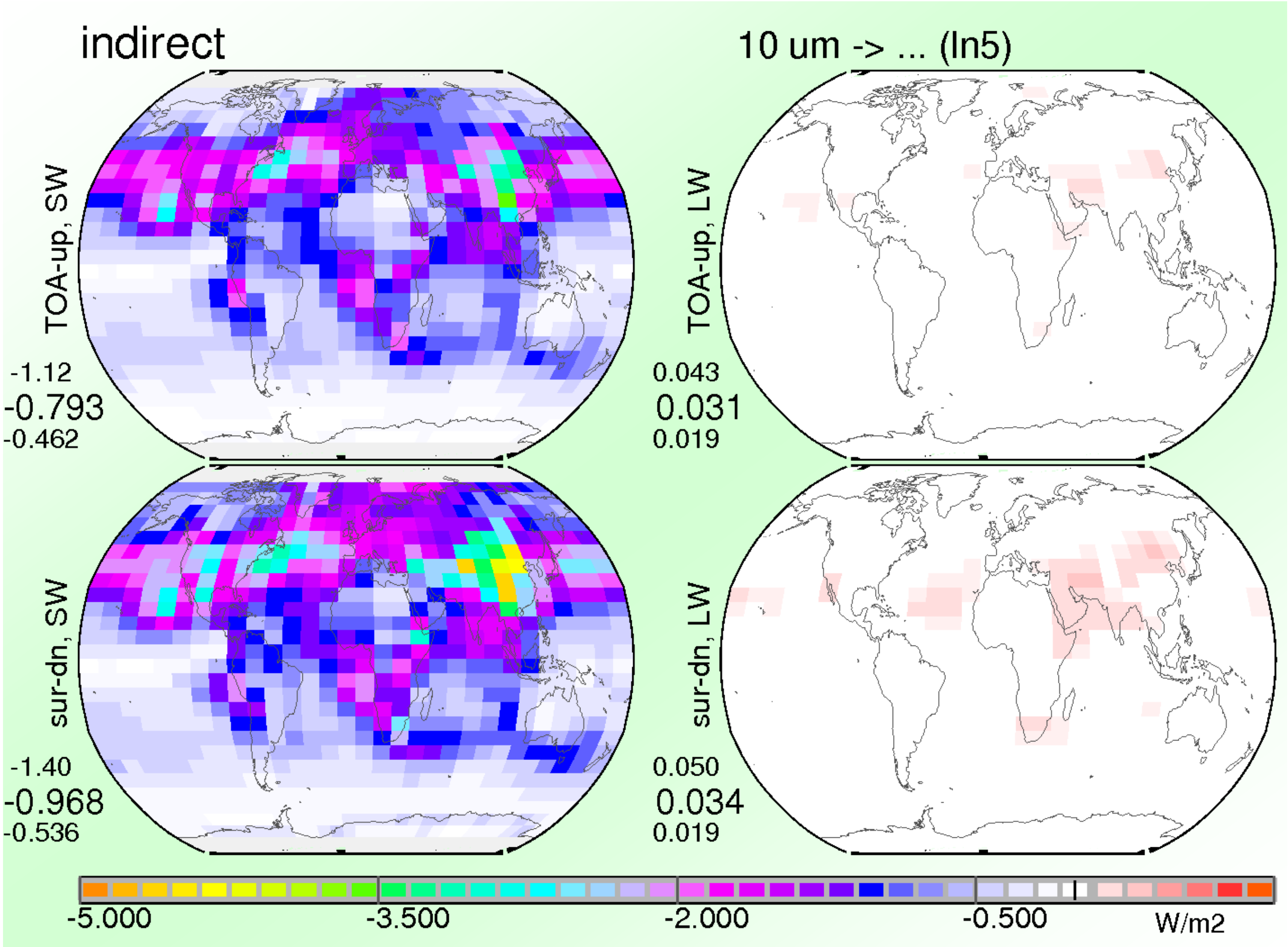


cloud drop size reductions



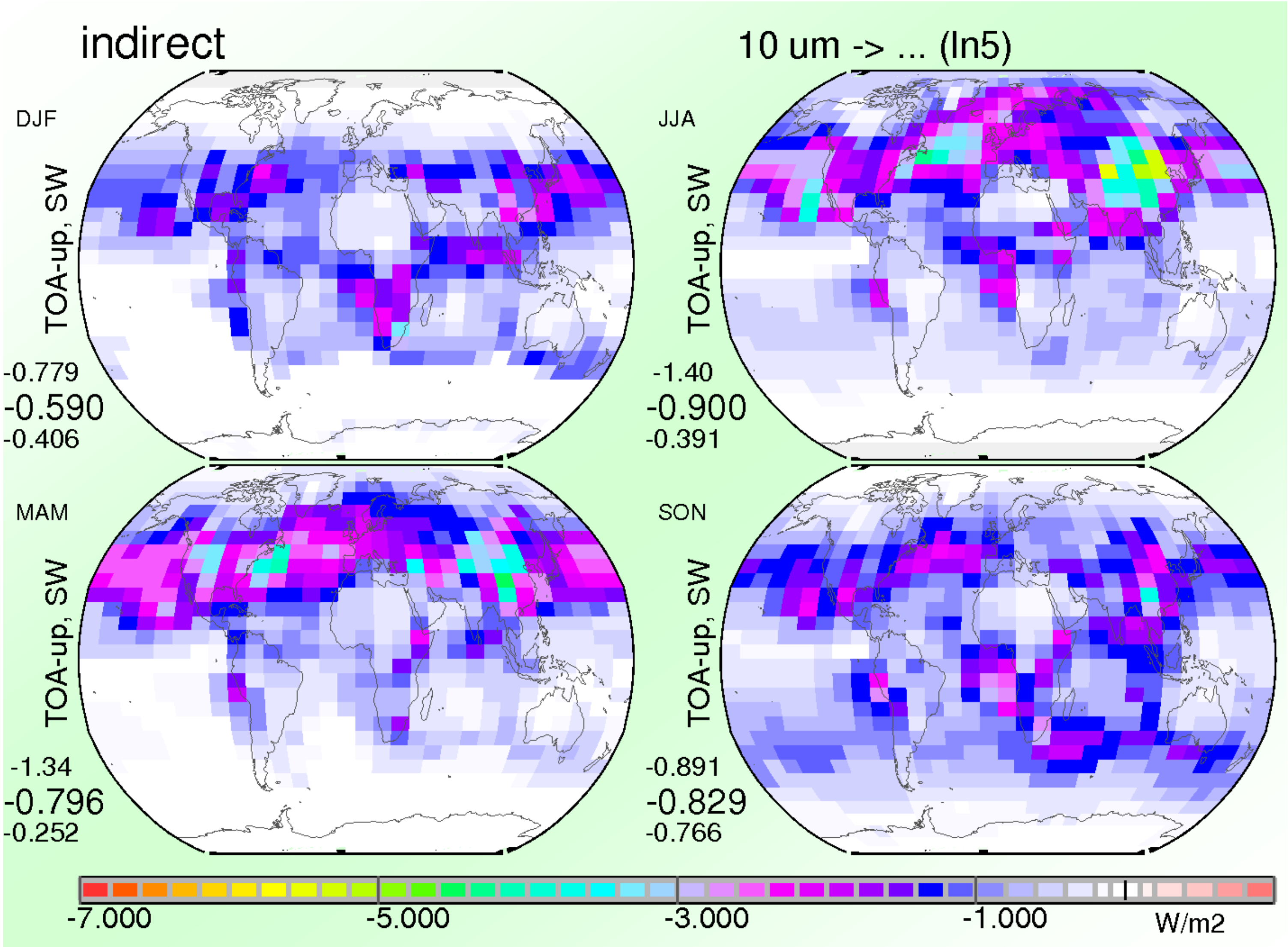
aerosol low cloud indirect effects

liquid water remains constant



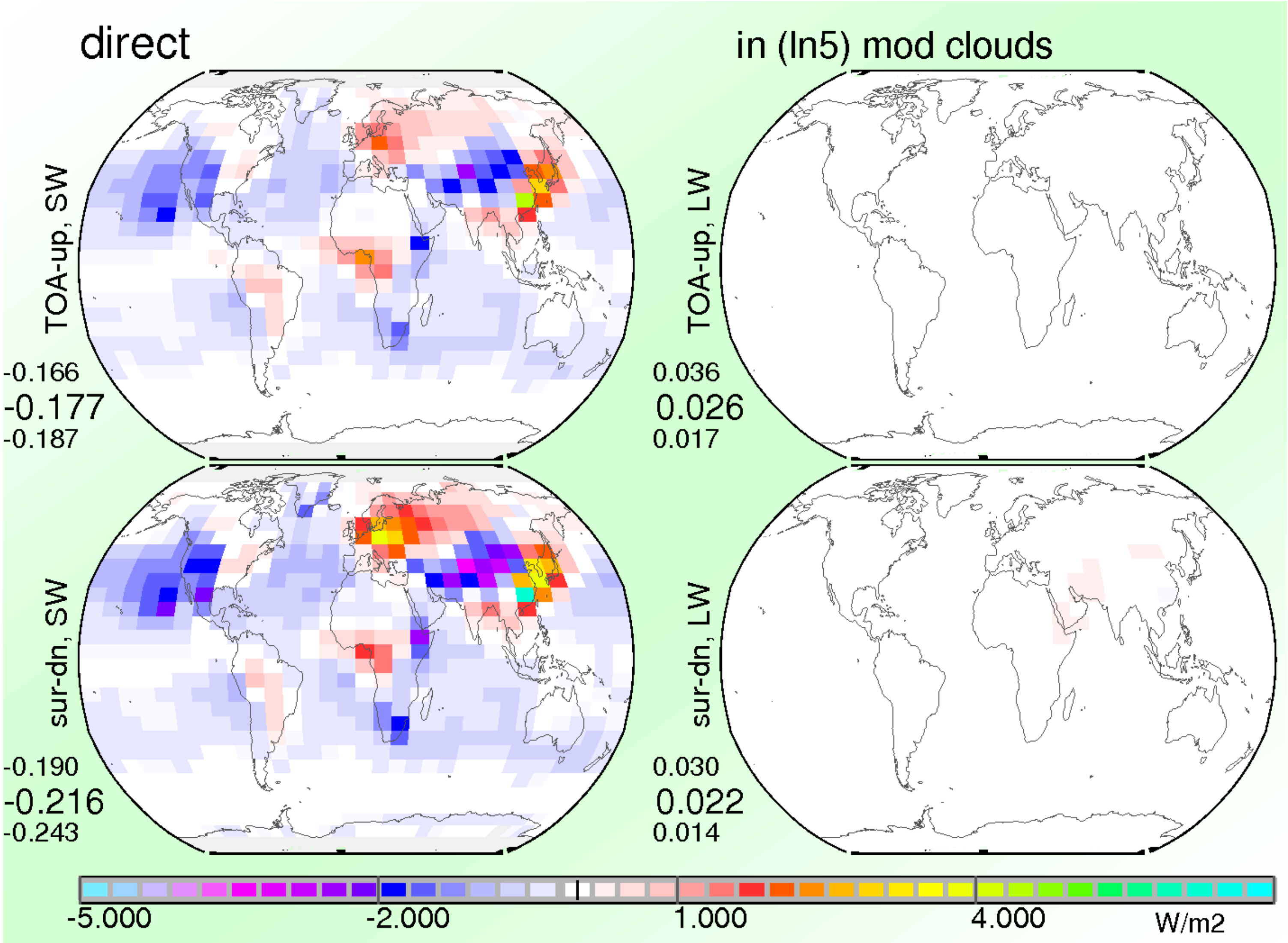
aerosol low cloud indirect effects

liquid water remains constant



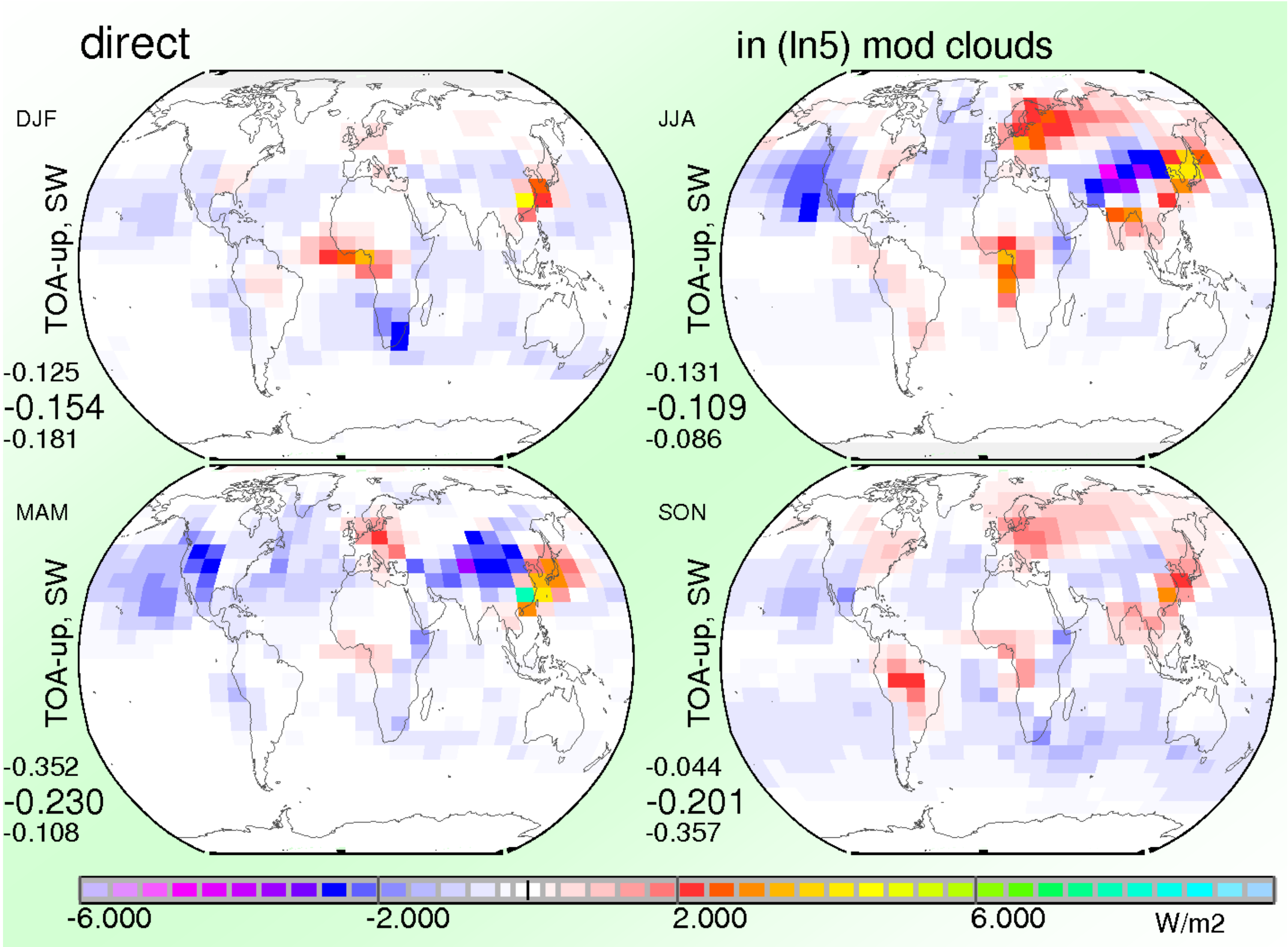
direct forcing: … - 0. W/m2

strongest regional contrasts in NH spring



direct forcing: only - 0.18 W/m2

indirect → brighter clouds → direct is halved



summary

- **climatologies**
  - **of atmospheric and surface properties in combination with off-line radiative transfer:**
  - **a quick path to explore regional/seasonal or parameter variability in the global contexts**

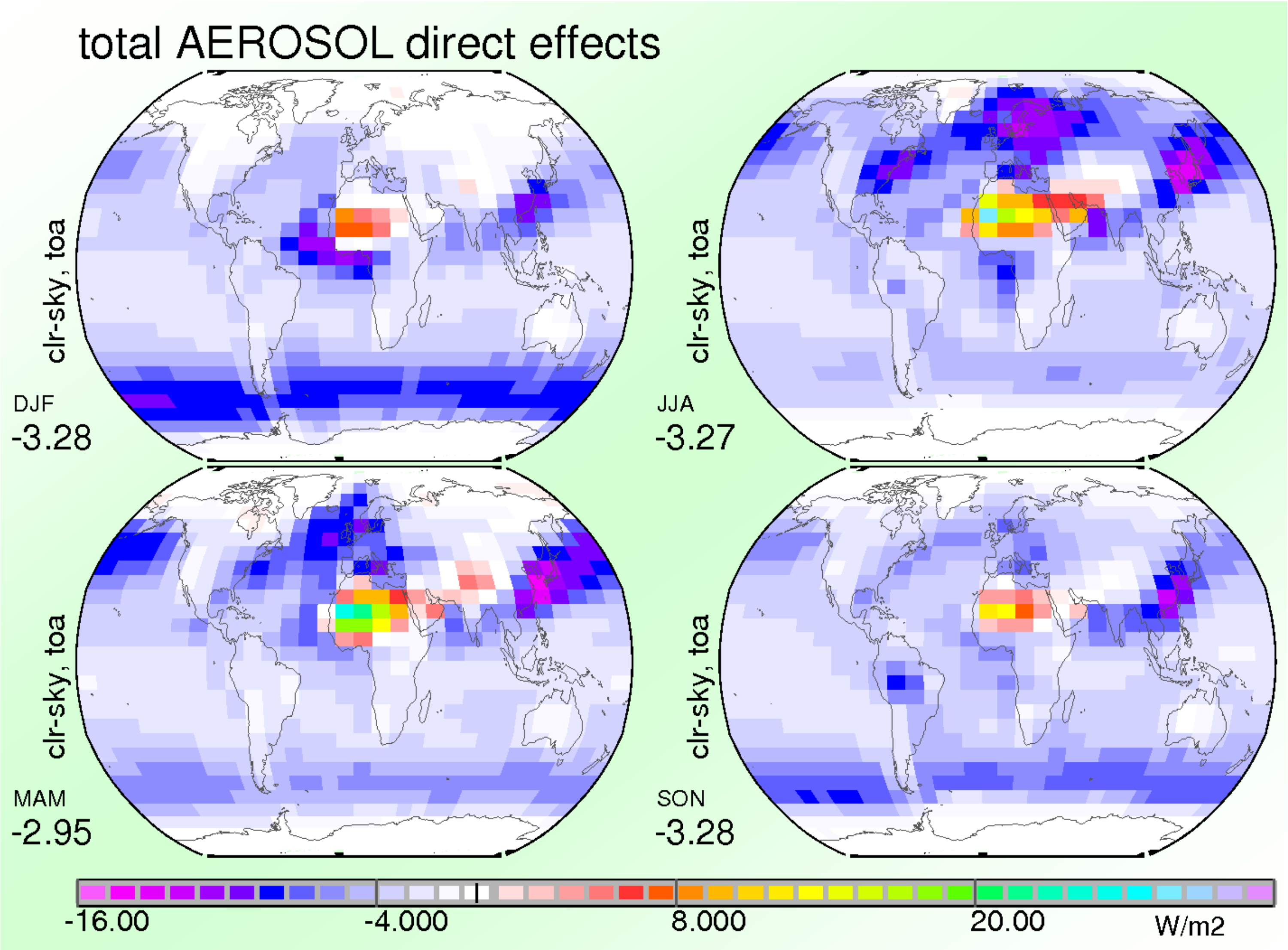
- **application-example: aerosol climate impacts**
  - **spatial and temporal variability**
  - **direct forcing ca - 0.35 W/m2 (global avg)**
  - **indirect forcing ca - 0.75 W/m2 (global avg)**

… and the combined effect is smaller than the sum

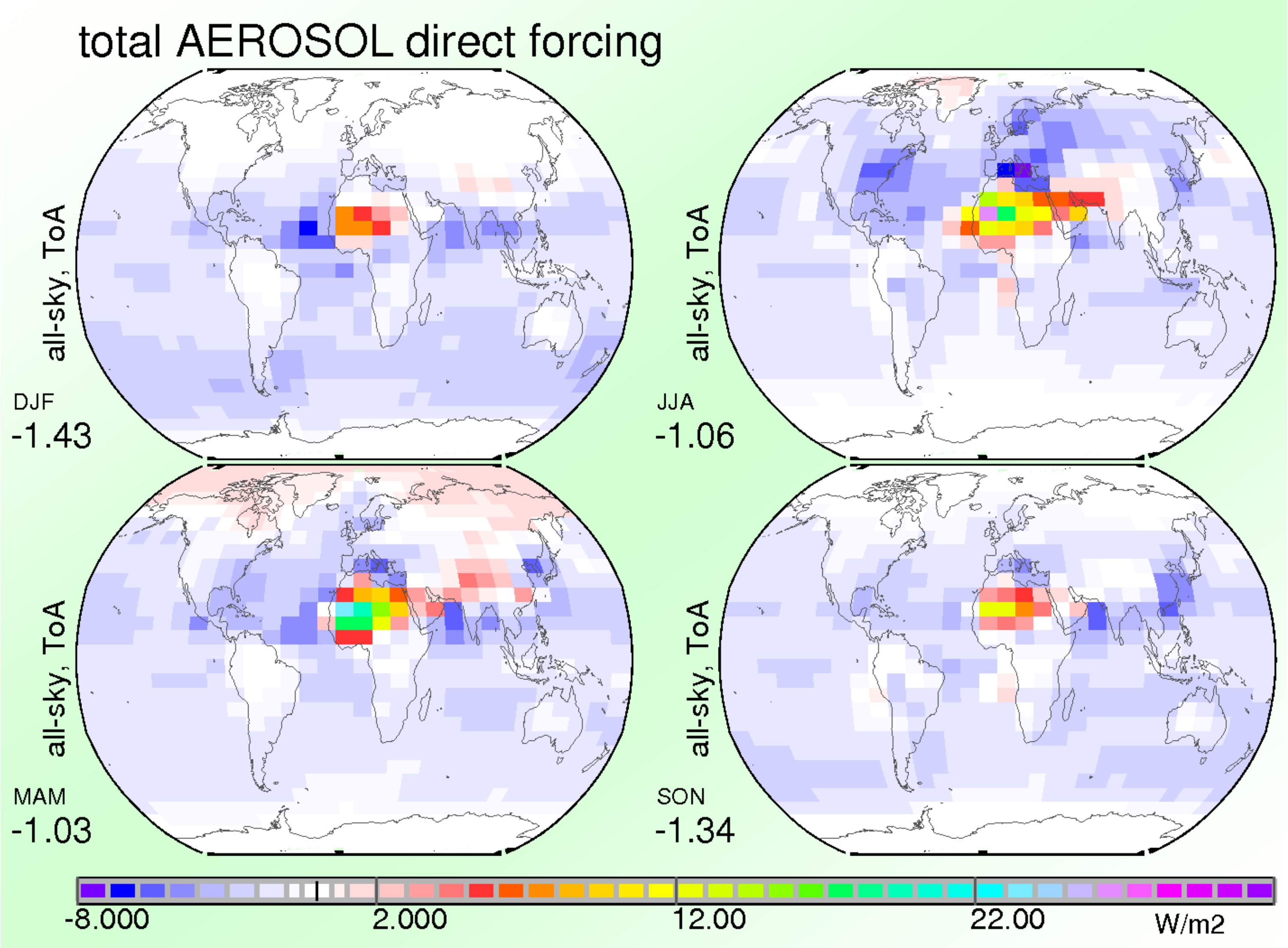
extra slides

- on seasonal details of aerosol direct radiative effects
  - total (SW and LW impacts combined)
  - solar (SW impacts only)
    - note, anthropogenic impacts are a fraction of the solar (SW) impact, as anthropogenic contribution as they may occur to the coarse mode (e.g. dust) are ignored

SW+LW … at ToA, clear-sky

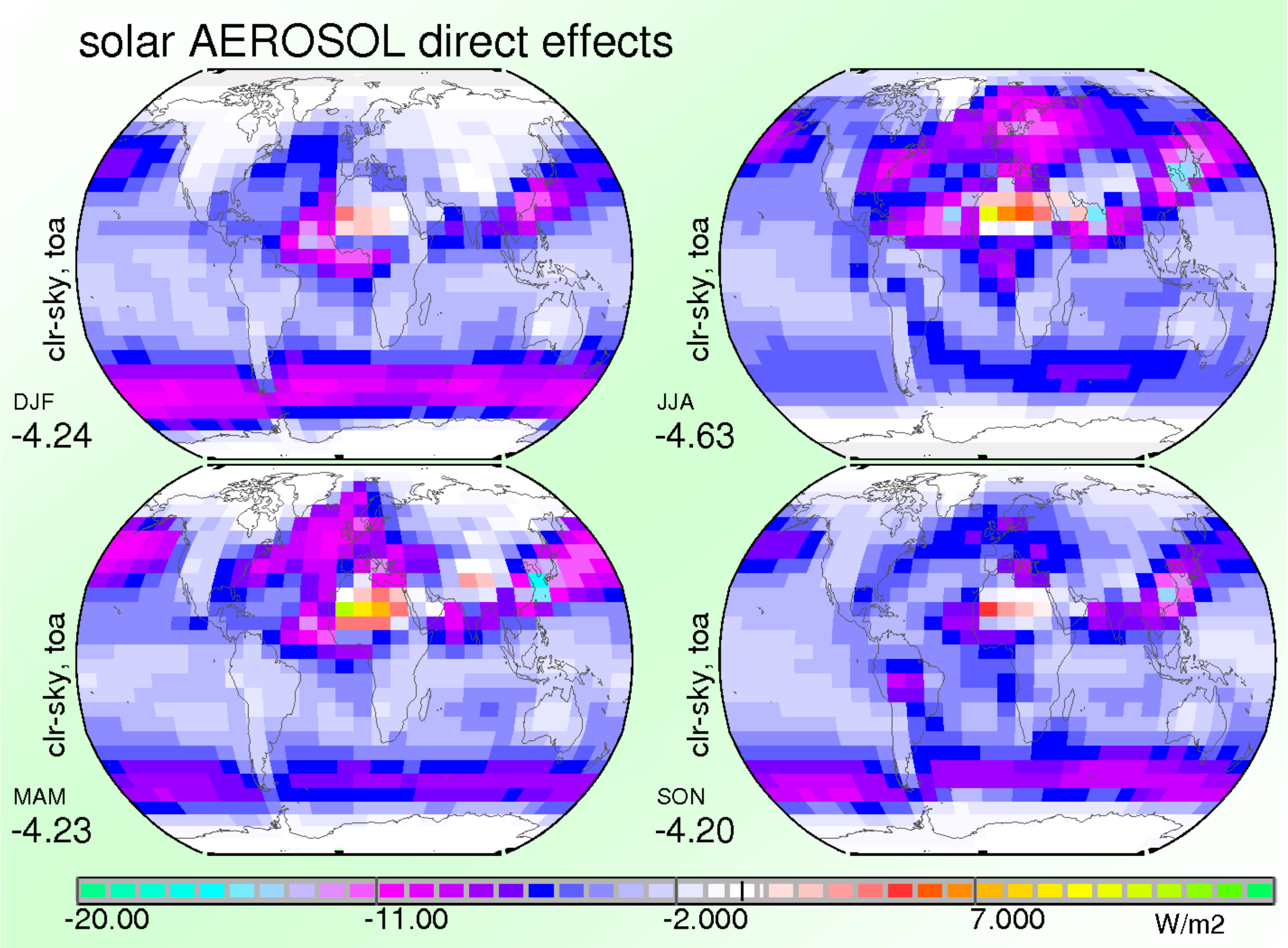


SW+LW … at ToA, all-sky

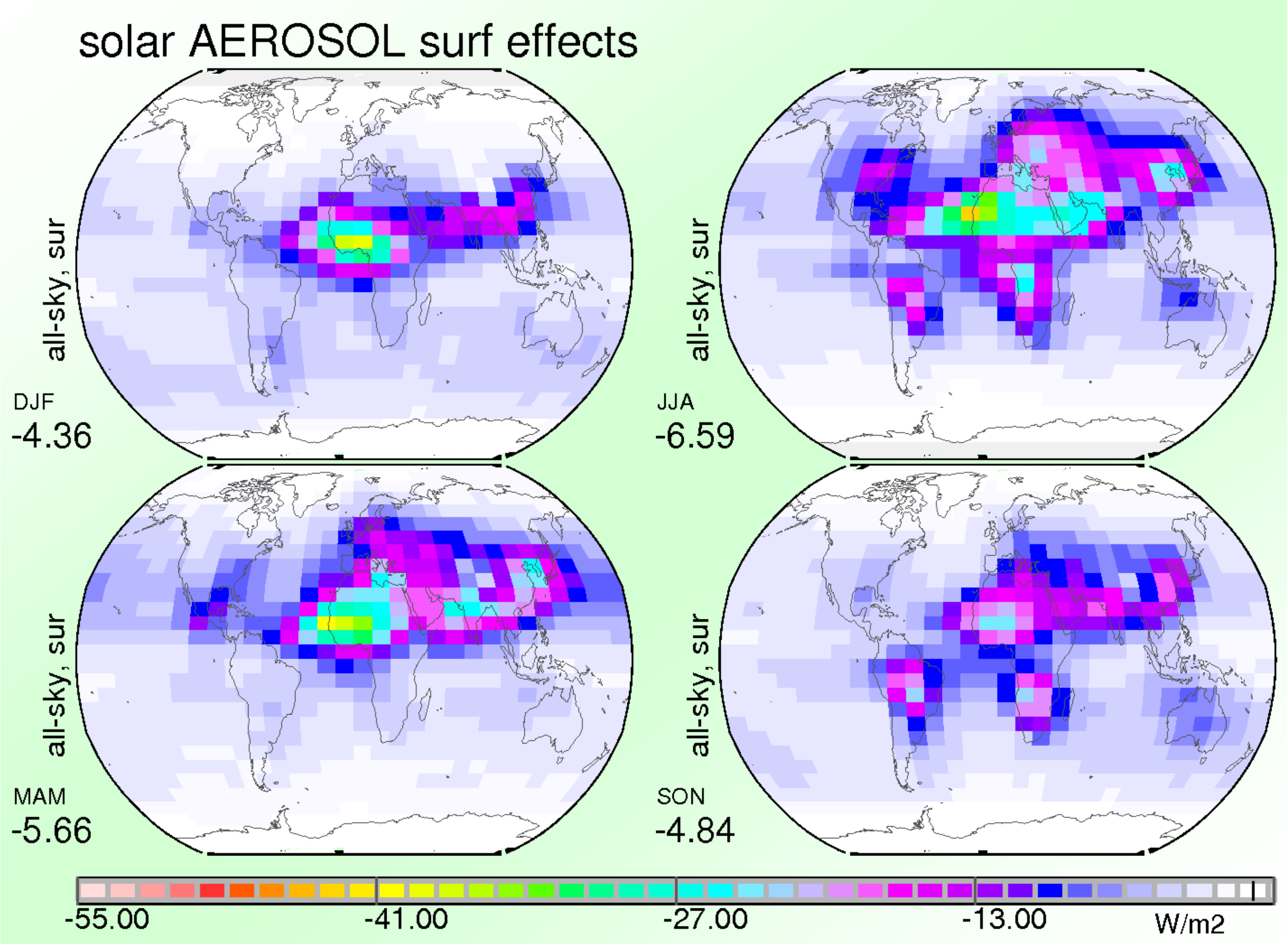


SW … at TOA, clear-sky

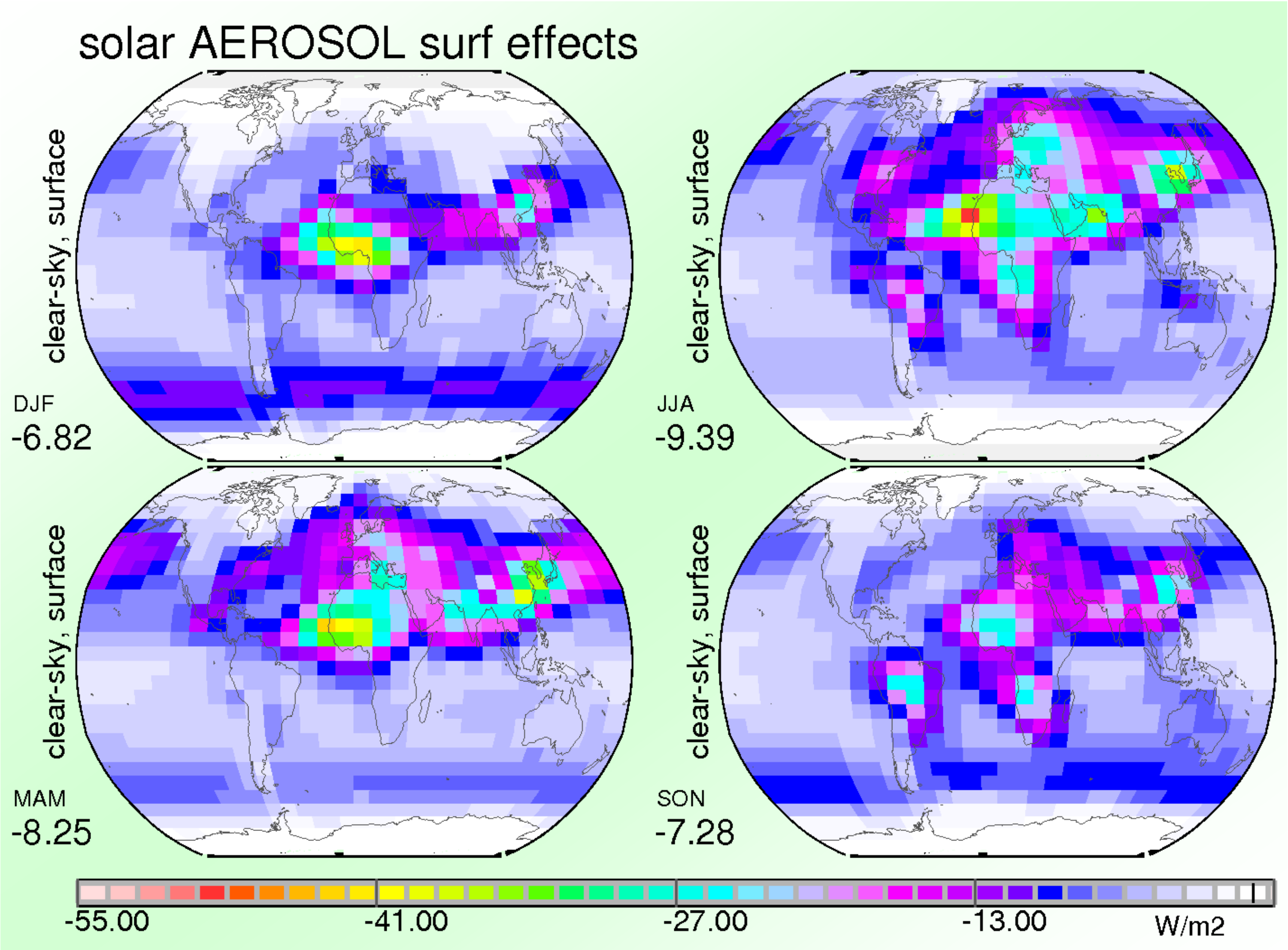
what a satellite "sees"



SW … at surface, all-sky



SW … at surface, clear-sky



SW ... in atmos, all-sky