global remote sensing of AEROSOL and CLOUDS

a path to understand aerosol cloud interactions?

Stefan Kinne

MPI-Meteorology, Hamburg

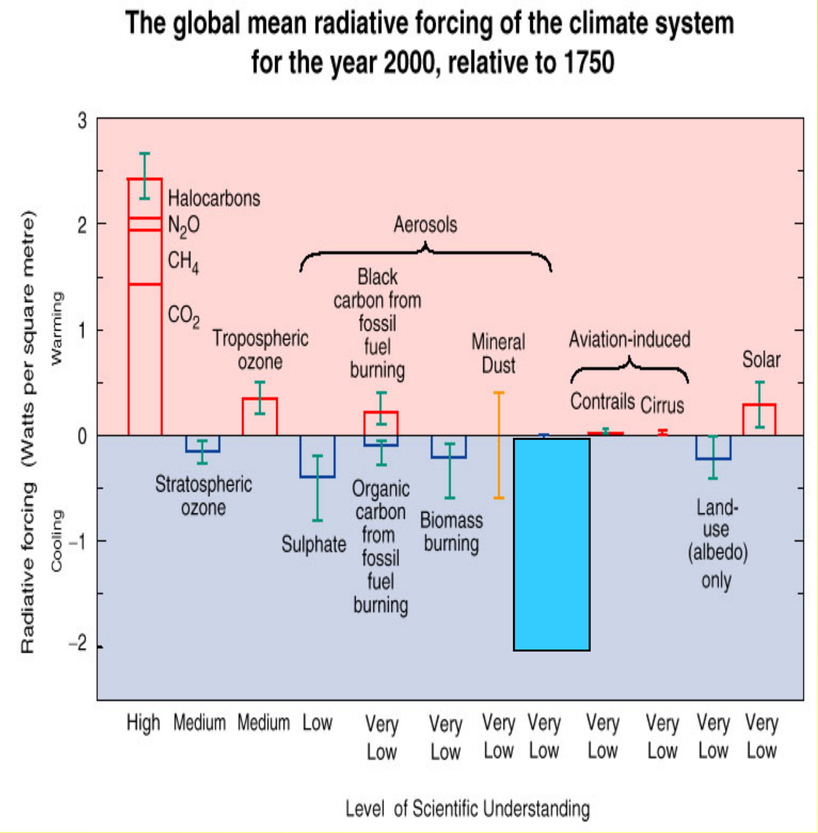
AEROSOL can influence CLOUDS

"the aerosol indirect effects"

- **in simulations of the anthropogenic impact on the Earth climate ⇨**

…the '*aerosol indirect effect*' (the influence of aerosol on clouds) carries one of the largest uncertainties

(we 'think' the indirect effects overall contribute to COOLING)



why uncertainties ?

- limited (local) understanding of processes
- processes can increase or decrease ‘brightness’
  - added CCN ⇨ more and smaller cloud droplets
    - ⇨ increase optical depth: stronger cloud signal to space
    - ⇨ suppress precipitation: exteneded (stronger) cloud signal
  - added ice nuclei a more precipitation ‘starters’
    - ⇨ suppress precipitation: shortened (weaker) cloud signal
  - aerosol layer warming
    - ⇨ suppress convection: weaker cloud signal (fewer clouds)
    - ⇨ delay and stronger conv: weaker cloud signal (stronger greenhouse effect via higher tops)

… overall impact and even overall sign is in question !

What to do?

- **look at DATA !**

  1. **investigate correlations of simultaneous retrievals for cloud and aerosol properties**

  2. **identify regions with strong signatures**

  3. ***investigate strong signatures in more detail and identify dominating processes***

  4. ***improve parameterizations in global modeling (observed patterns must be reproduced)***

What data?

- **MODIS daily 1^0*1^0 lat/lon data-fields**

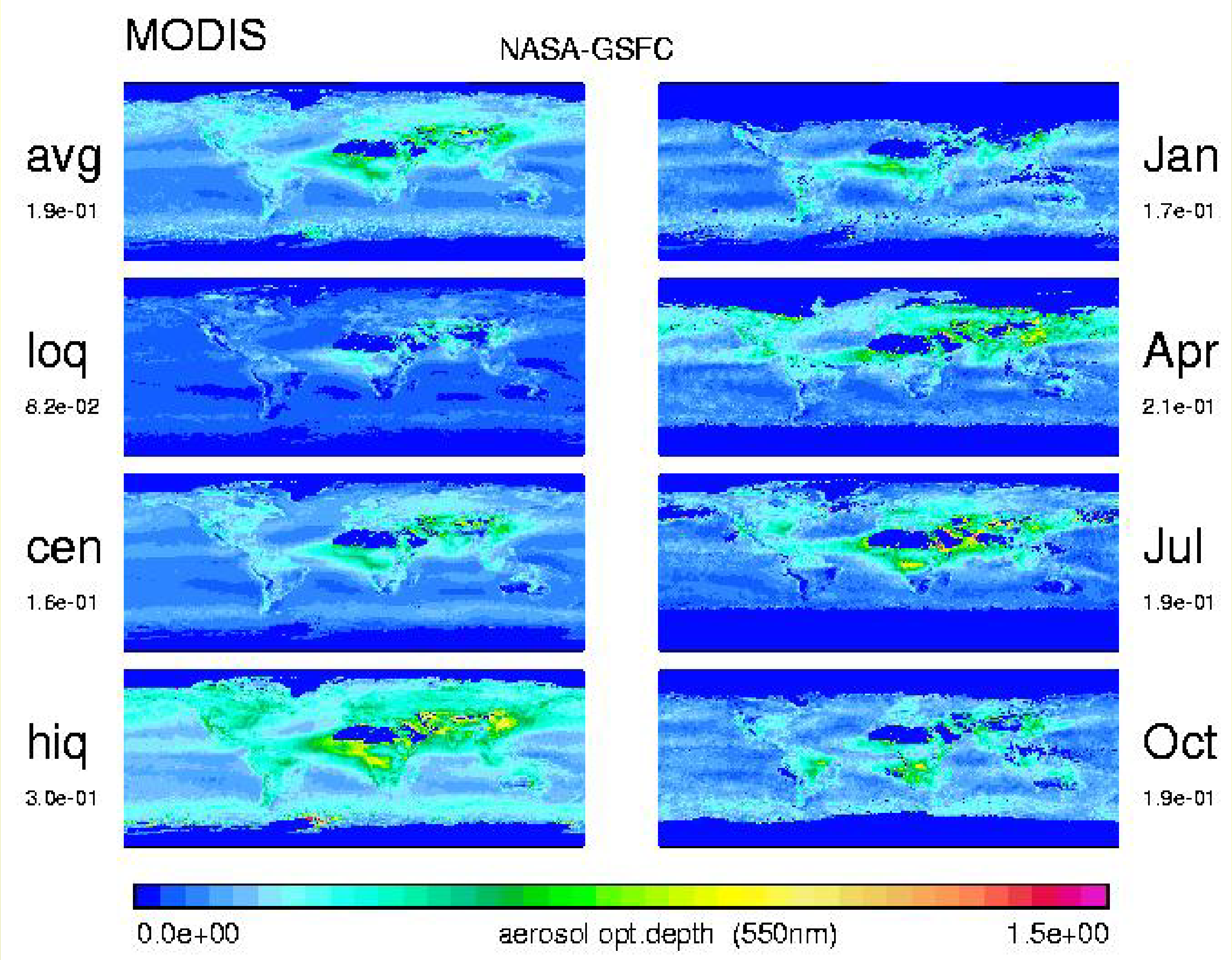
available data fields *(Mar/2000 - Feb/2001)*

- ***Aerosol***
  - optical depth, Angstrom parameter, effective radius, optical depth for sizes smaller than 1μm
- ***Clouds***
  - optical depth, liquid water content, effective radius, cloud-fraction, cloud top temperature
- ***Gases***
  - water vapor, ozone

***combine data for further specification** (e.g. 'low' cloud)*

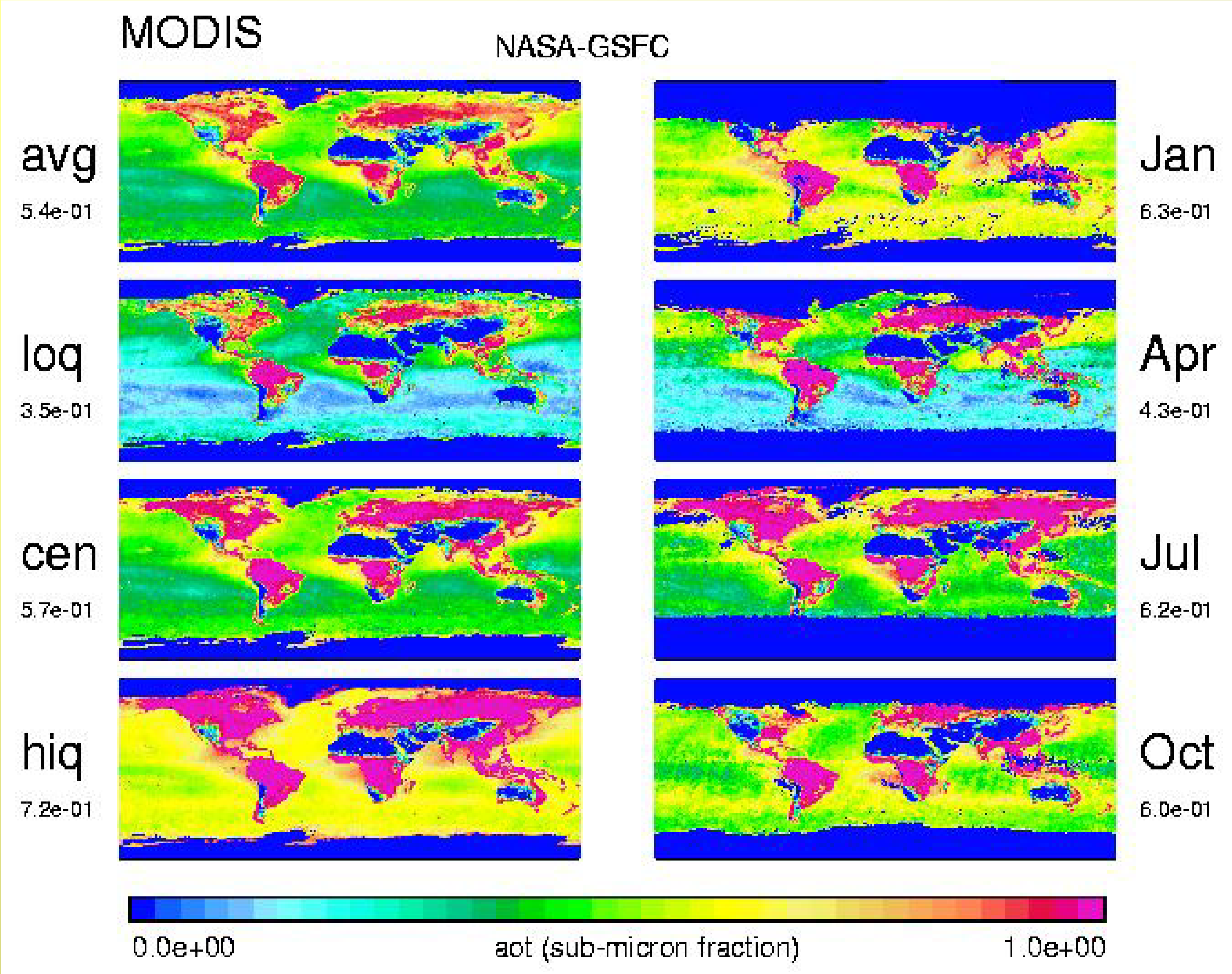
aot MODIS (3/2000-2/2001)

- **avg**
  average
- **loq**
  lower quartile (5-70%)
- **cen**
  central range (30-70%)
- **hiq**
  high quartile (70-95%)



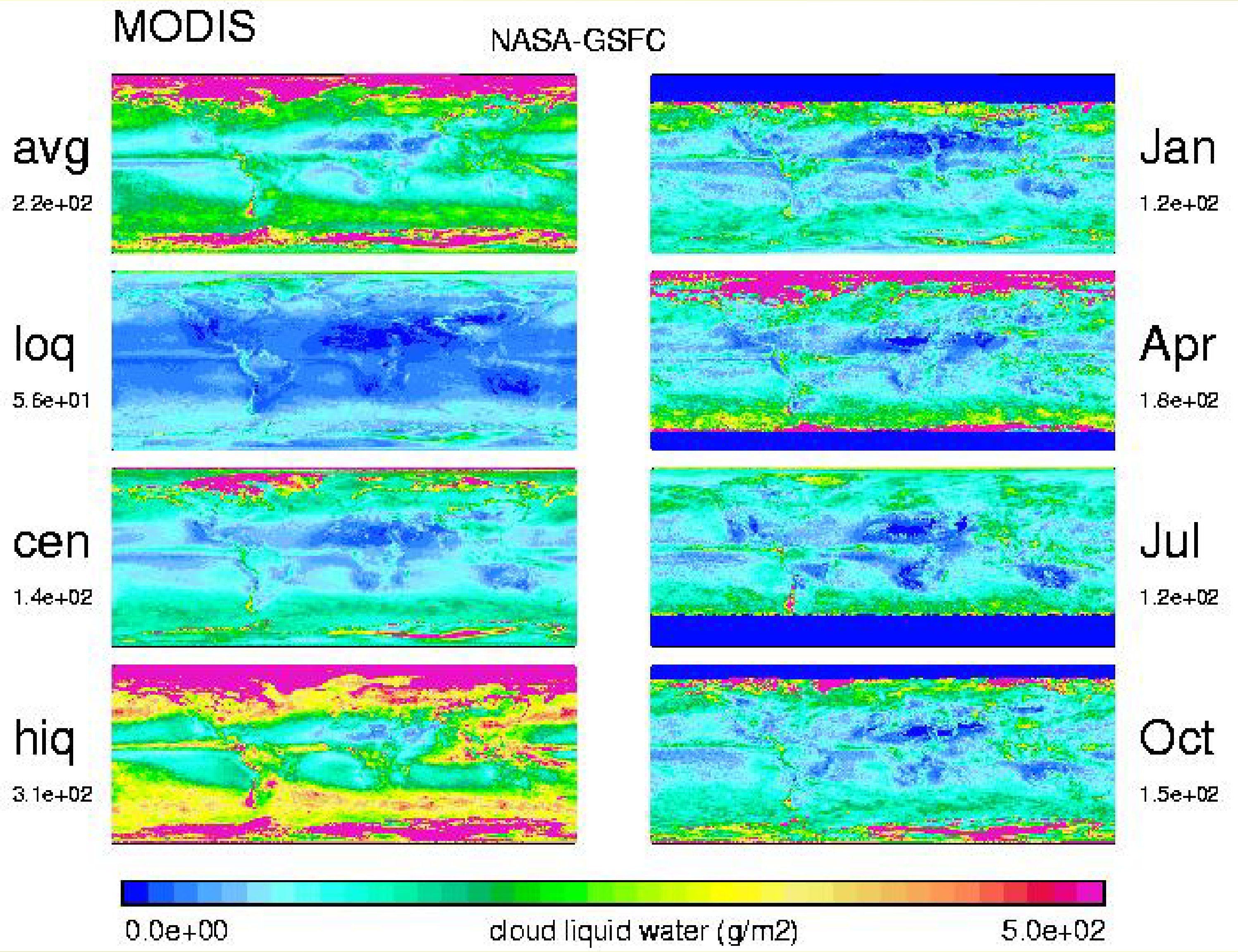
aot, small mode fraction MODIS

- **avg**
  average
- **loq**
  lower quartile (5-70%)
- **cen**
  central range (30-70%)
- **hiq**
  high quartile (70-95%)



liquid water content - MODIS

- **avg**
  average
- **loq**
  lower quartile (5-70%)
- **cen**
  central range (30-70%)
- **hiq**
  high quartile (70-95%)



… but be aware

- data accuracy may be limited

  (although only trends are investigated … accuracy matters)

  – *examples for MODIS retrievals*

    - aerosol - aot: too large over land, too low for dust
    - clouds - eff. radius: too large for broken clouds

- aerosol-cloud correlations also include …
  influences of clouds on aerosol

    - aerosol removal — weaker aerosol signal
    - aerosol swelling — stronger aerosol signal
    - aerosol redistribution — stronger? aerosol signal

2 way- Correlations

A. pick a pair of co-located data-sets

B. rank data of the reference property

C. determine data averages of the reference property falling into the 5-30% and 70-95% PDF ranges

C. determine range associated data averages of the second property

D. determine correlation:

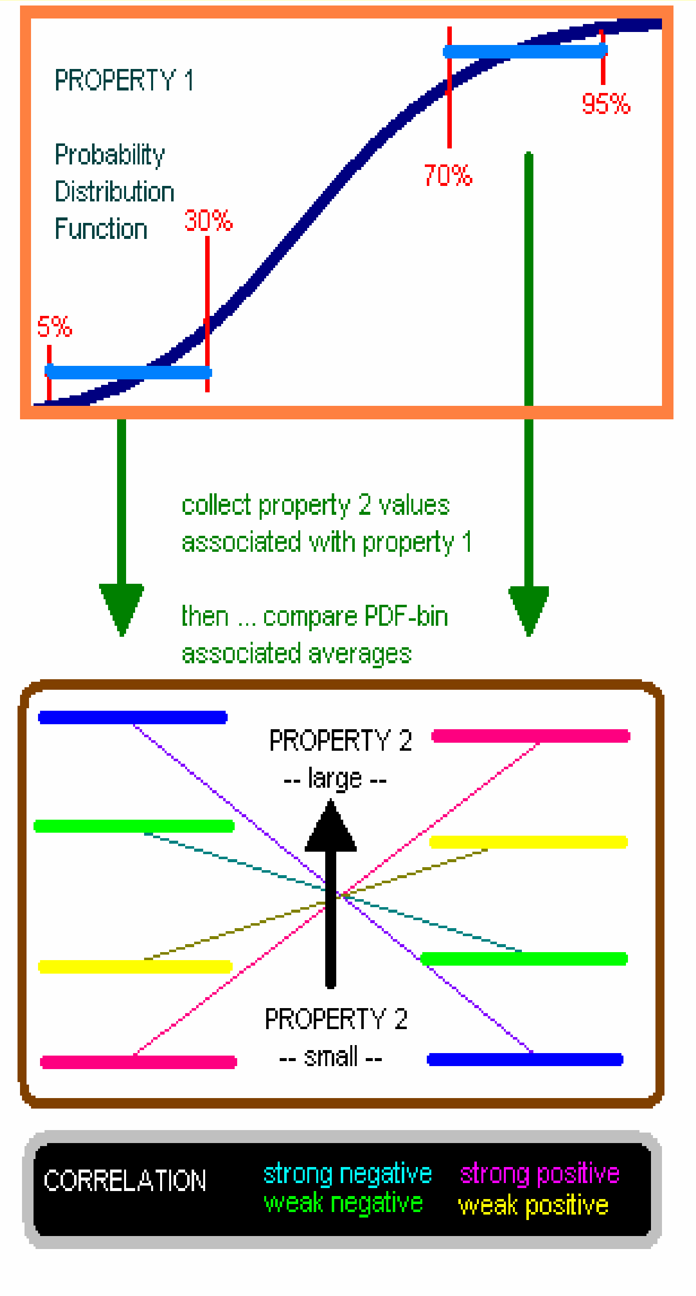
\+ slopes agree, - slopes disagree

E. determine correlation strength:

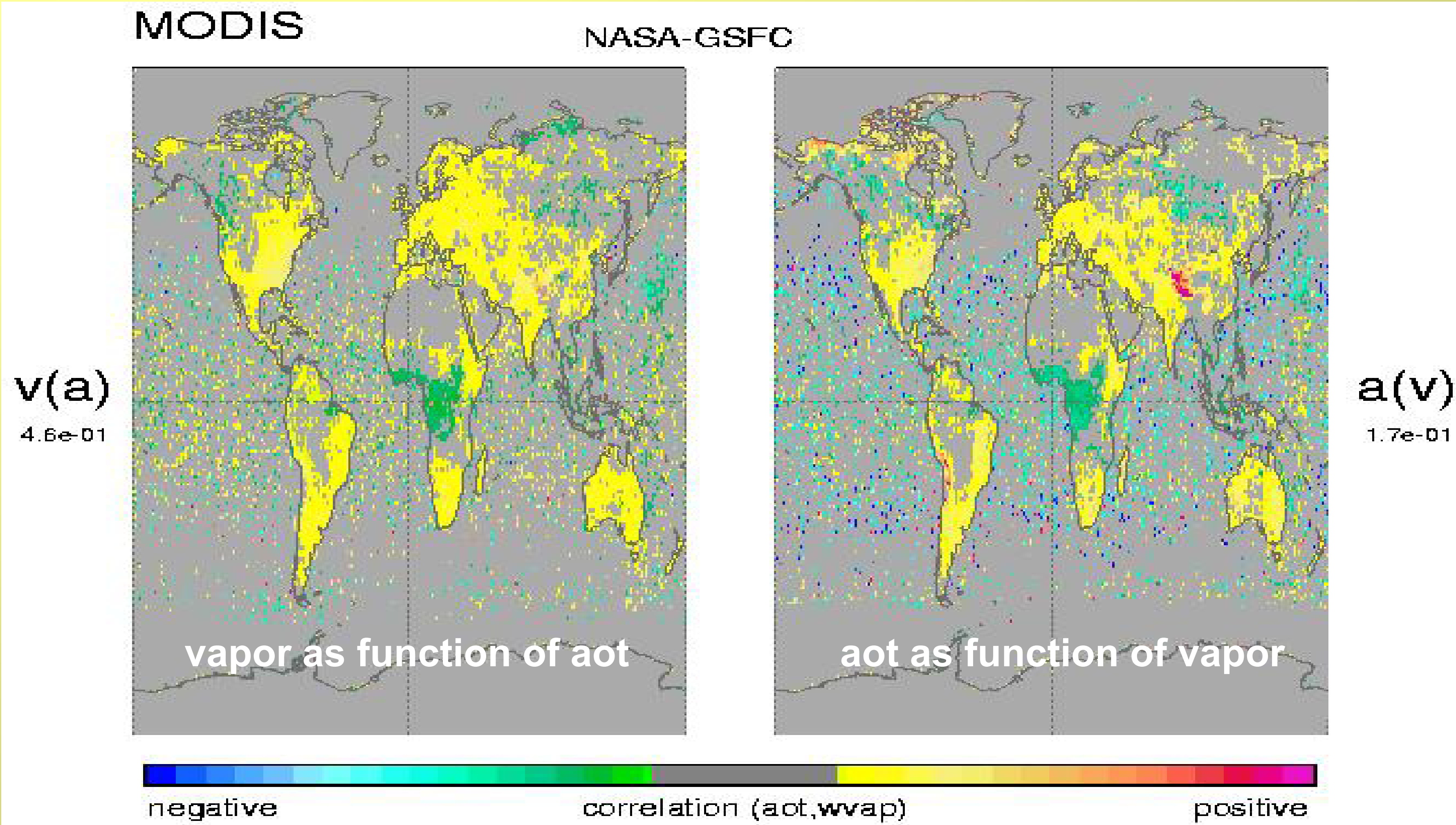
use normalized slope steepness

F. repeat - by exchanging properties

cumulative PDF of reference property



aerosol



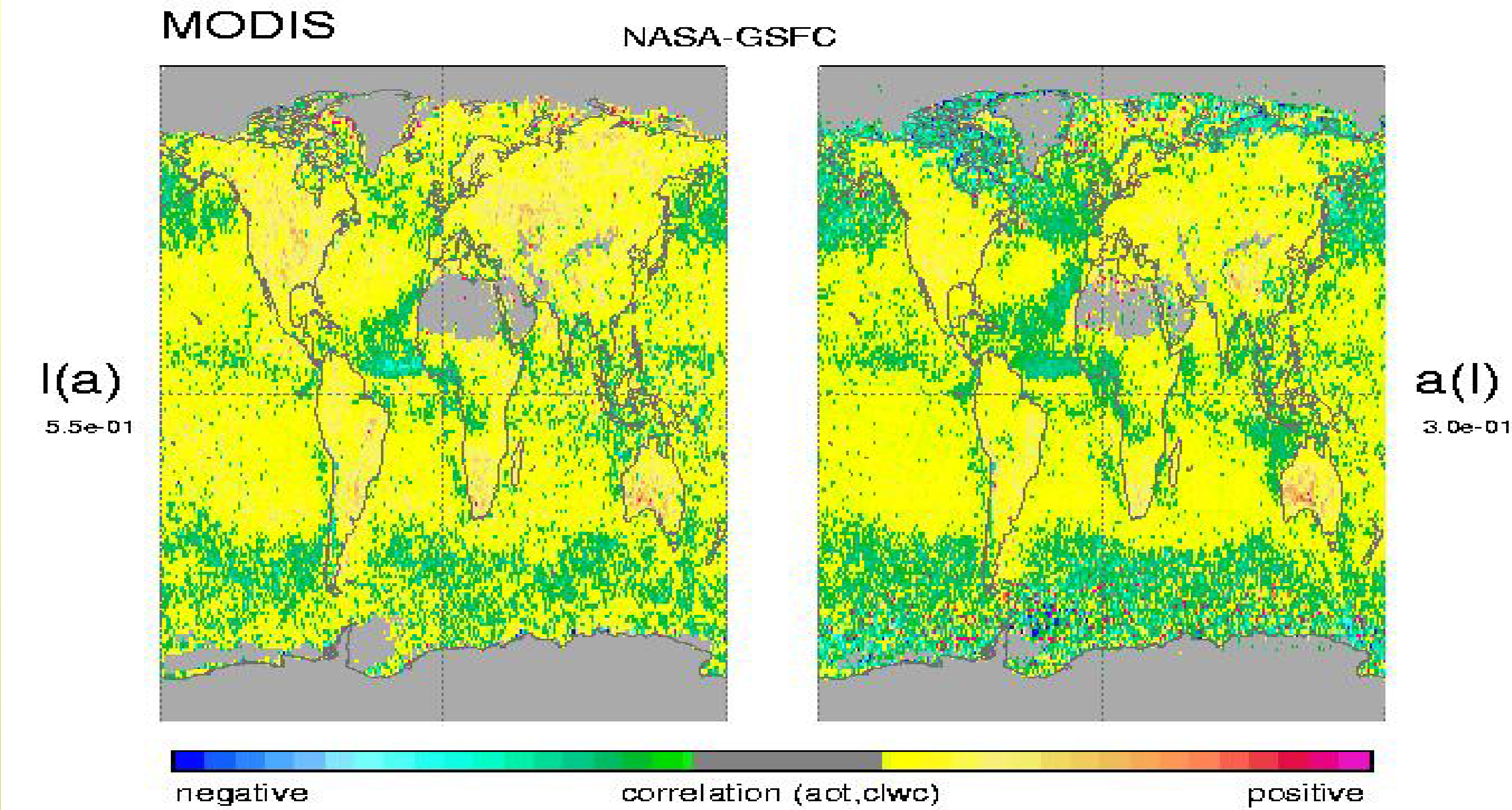
- **aerosol opt. depth (a) – water vapor column (v)**

high aerosol load when dry (biomass fires, wind blown dust)

explanations ?

RH effect on aerosol size vapor ~ sizes (and aot)

aerosol - cloud

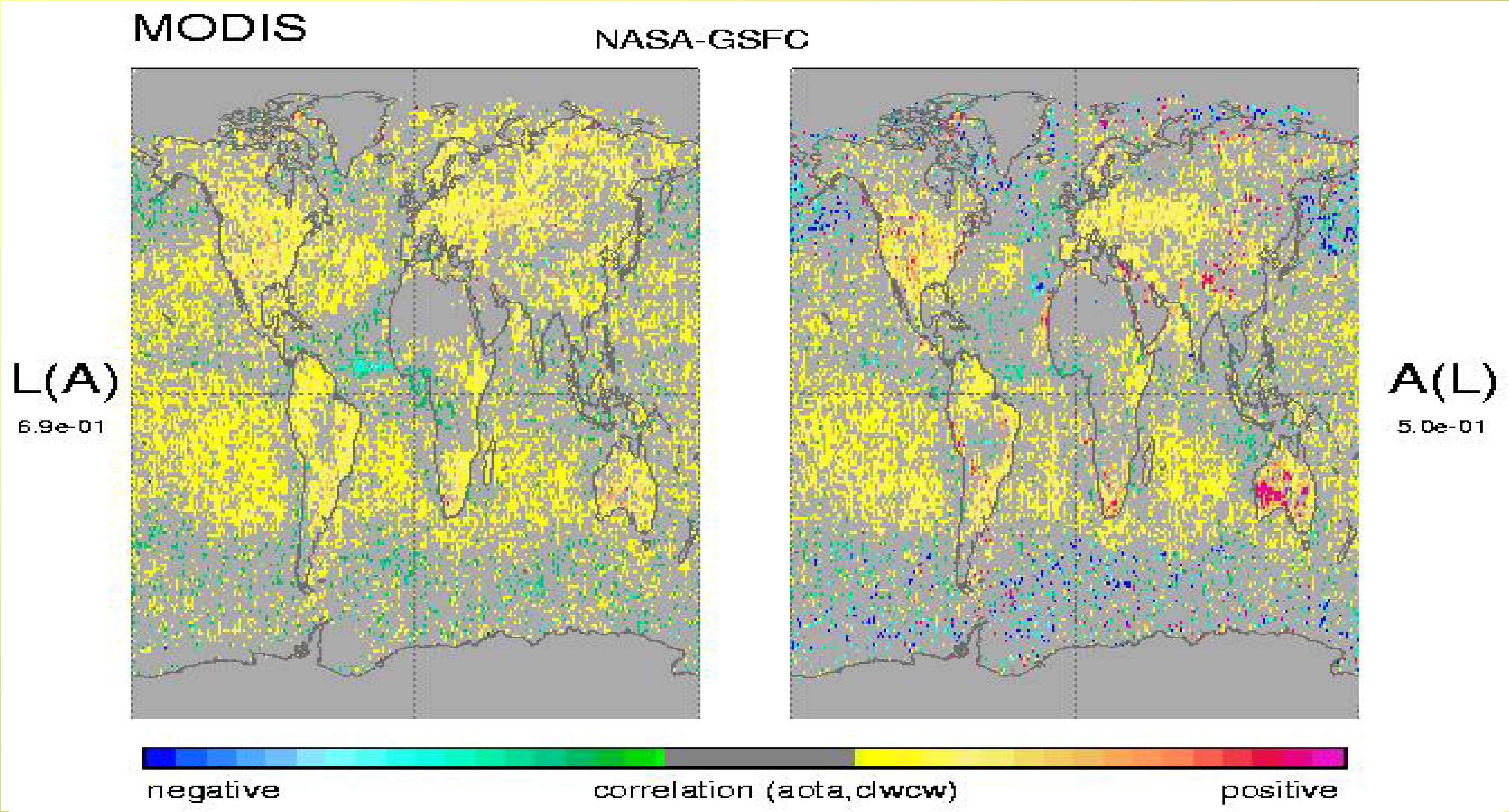


- **aerosol optical depth (a) – cloud liquid water (l)**

cloud removal dominant over aerosol swelling: no clouds ~ high aerosol load

aerosol swelling near clouds extended cloud-lifetime over land

aerosol - cloud



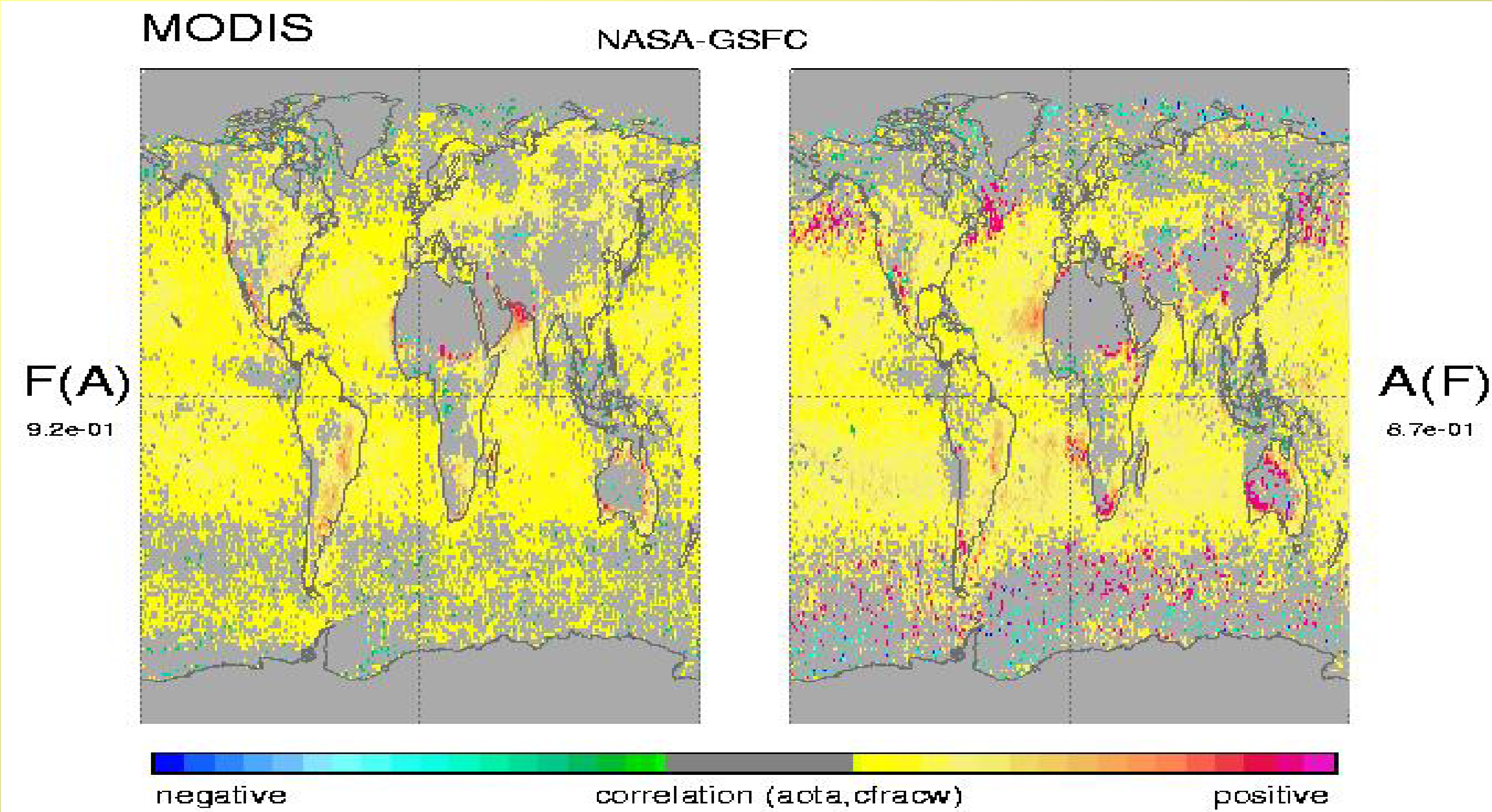
- **aerosol optical depth (A) – cloud liquid water (L)**

(accumulation mode) *(water cloud [T >260K])*

higher altitude dust signal disappears

land signal increases (+ lifetime?)

aerosol - cloud

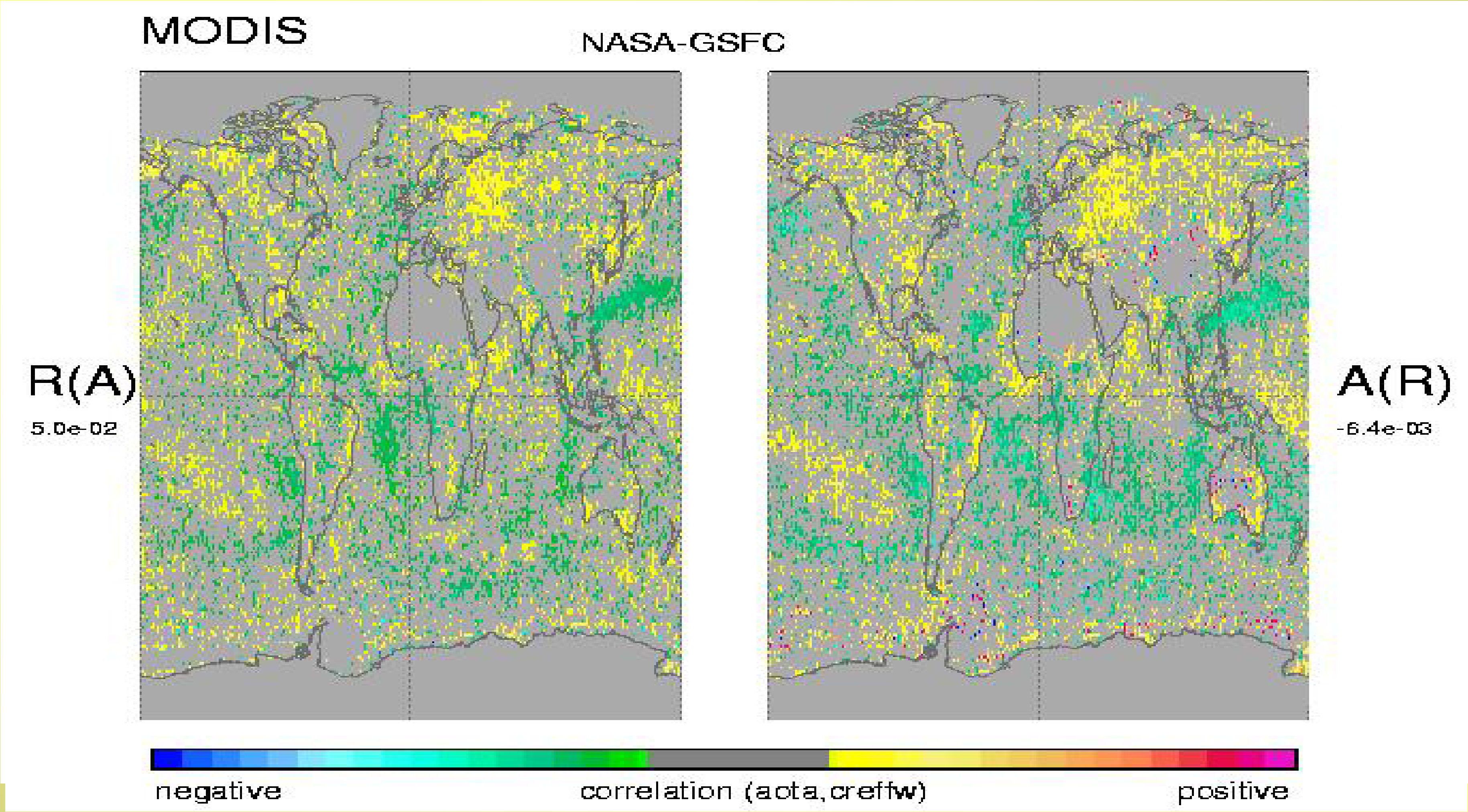


- **aerosol optical depth (A) – cloud fraction (F)**

  (accumulation mode) *(water cloud [T >260K])*

cloud extra lifetime (aerosol ⇨ clouds) or aerosol swelling (clouds ⇨ aerosol) or ?

aerosol - cloud



- **aerosol opt. depth (A) – cloud eff. radius (R)**

(accumulation mode) *(water cloud [T >260K])*

higher probability for the Twomey effect (especially over ocean shipping routes)

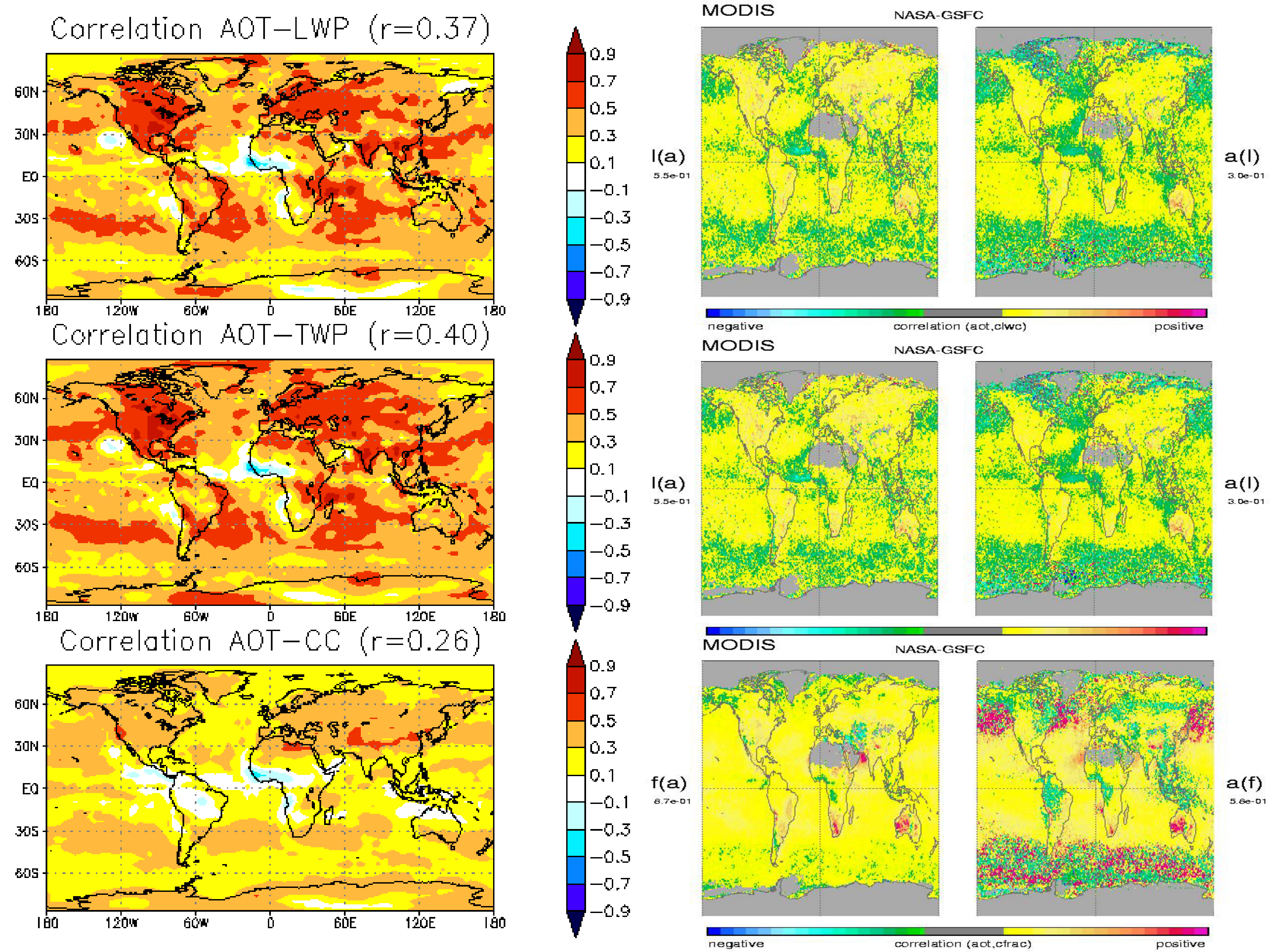
How do models compare ?

- **evaluate aerosol-cloud processes in global modeling** *(as an AeroCom activity)*
  - **correlations of simulated data-fields have to match the correlation patterns of the data !** *…do they ?*

a first example:

  - **ECHAM4 correlation coefficients** ***(by U.Lohmann)***
    [‘cc’ is similar but looks at the entire data volume]
  - **for aot (a) vs total water content (l)**
  - **for aot (a) vs liquid water(cloud) content (L)**
  - **for aot (a) vs cloud fraction (f)**
    - **comparions are shown next (beware of diff. scales)**

    … and major correlation patterns are reproduced !


Correlation AOT–LWP (r=0.37)
Correlation AOT–TWP (r=0.40)
Correlation AOT–CC (r=0.26)
60N
30N
EQ
30S
60S
180
120W
60W
0
60E
120E
180
0.9
0.7
0.5
0.3
0.1
−0.1
−0.3
−0.5
−0.7
−0.9
MODIS
NASA-GSFC
l(a)
5.5e-01
a(l)
3.0e-01
negative
correlation (aot,clwc)
positive
f(a)
6.7e-01
a(f)
5.8e-01
correlation (aot,cfrac)

Outlook

since initial investigations:

- **MODIS cloud data were reprocessed**
- **quality filters were applied to better distinguish between impacts to/from**
  - **ice clouds**
  - **mixed clouds**
  - **water clouds**
    - **Q: is the positive correlation between cloud-top and aot a low cloud effect only or could it support the idea of delayed but more vigorous convection?**

extras

General Thoughts

- **data need to be consistent – if they are not we need to know why (deviations among data are often beyond combined uncertainties) INVESTIGE**
- **global aerosol data are needed at high detail not currently supplied from space** ***(number concentration, mass, aerosol absorption)*** **and different (space) sensors have individual strengths INTEGRATE**
- **evaluations based on a product** ***(aerosol radiative forcing)*** **tuned at an intermediate step** ***(total 'aot')*** **only tells half of the story UNDERSTAND** ⇨ *confidence in modeling !*
- **understanding modeling requires the use of consistent data input ACHIEVE COMPARABILITY**
- **correlations between 'quasi' simultaneous retrievals of cloud and aerosol data serve as a tool to judge the modeling skill on aerosol-cloud processing (beyond local scales) EVALUATE**

Outlook

since initial investigations:

- MODIS cloud data were reprocessed
- quality filters were applied to better distinguish between impacts to/from
  - ice clouds
  - mixed clouds
  - water clouds
    - Q: is the positive correlation between cloud-top and aot a low cloud effect only or could it support the idea of delayed but more vigorous convection?