Evaluations

aerosol modules in global models

Stefan Kinne

MPI-Meteorology, Hamburg Germany

Michael Schulz, Christiane Textor, Sarah Guibert

LSCE, Gif-sur Yvette, France

Anthropogenic climatic impacts

- our understanding is based on models
- aerosol introduces one of the largest uncertainties ⇨
- ‘low understanding’ reflects deficiencies in modeling: let us have a closer look at aerosol modules in global models

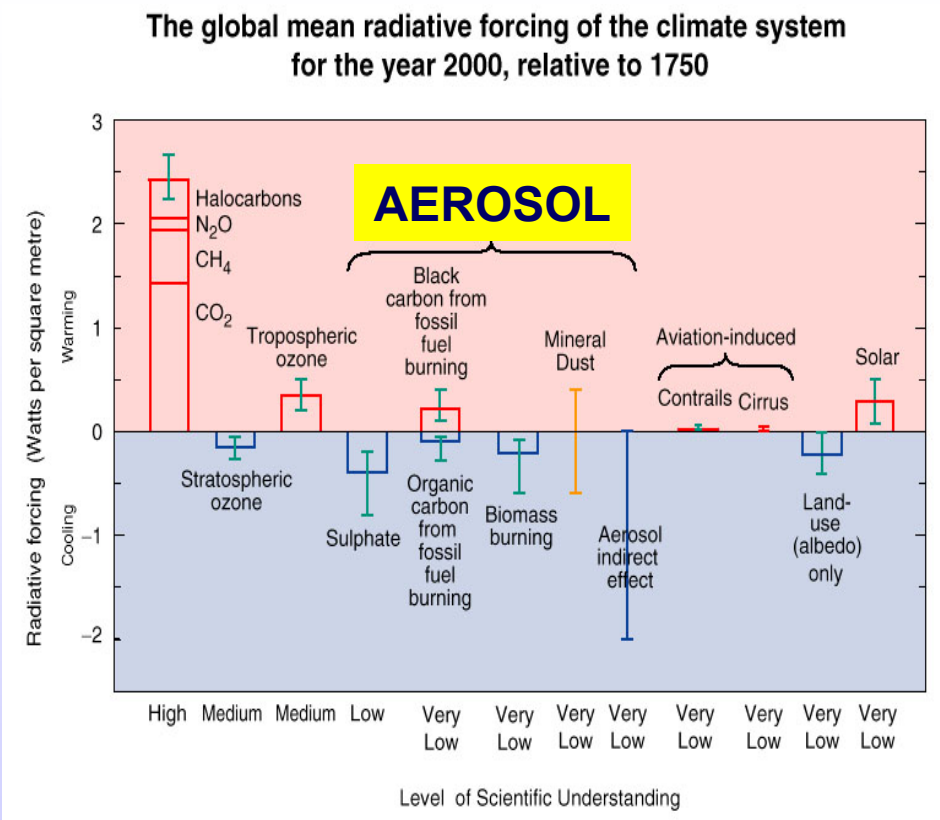
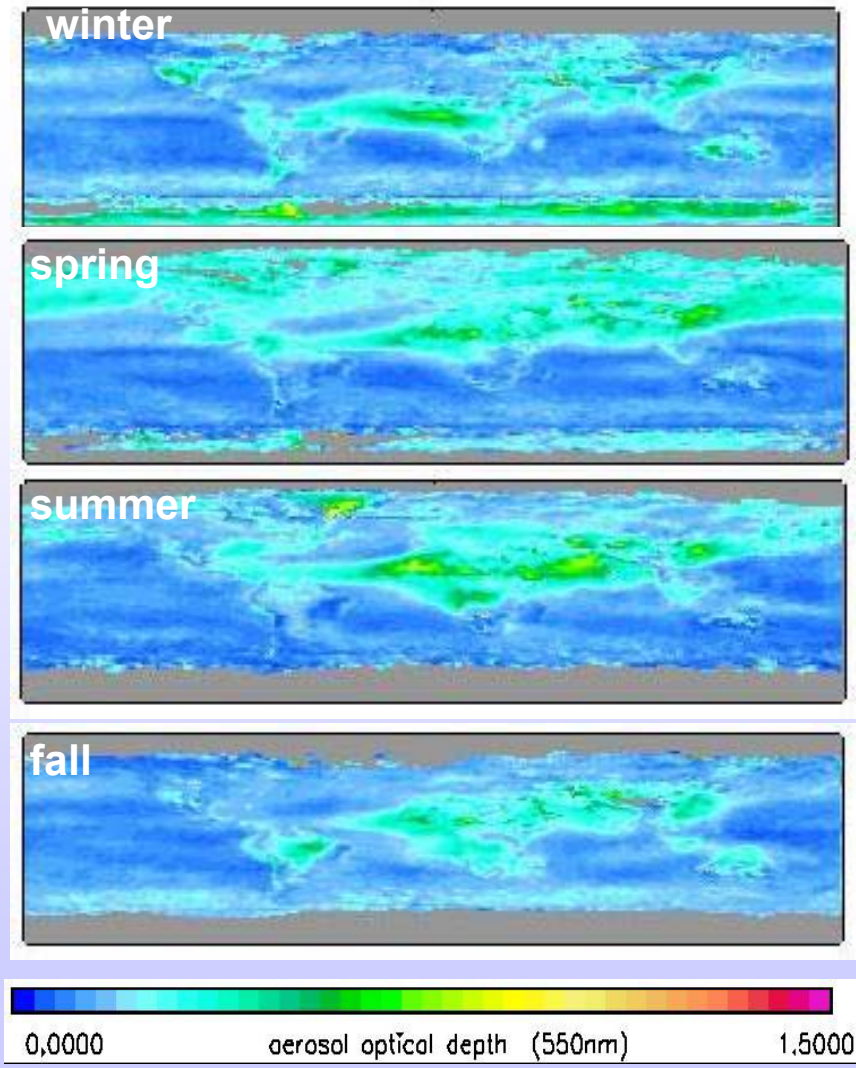


illustration of ‘forced’ changes to the radiative energy budget at the top of the atmosphere

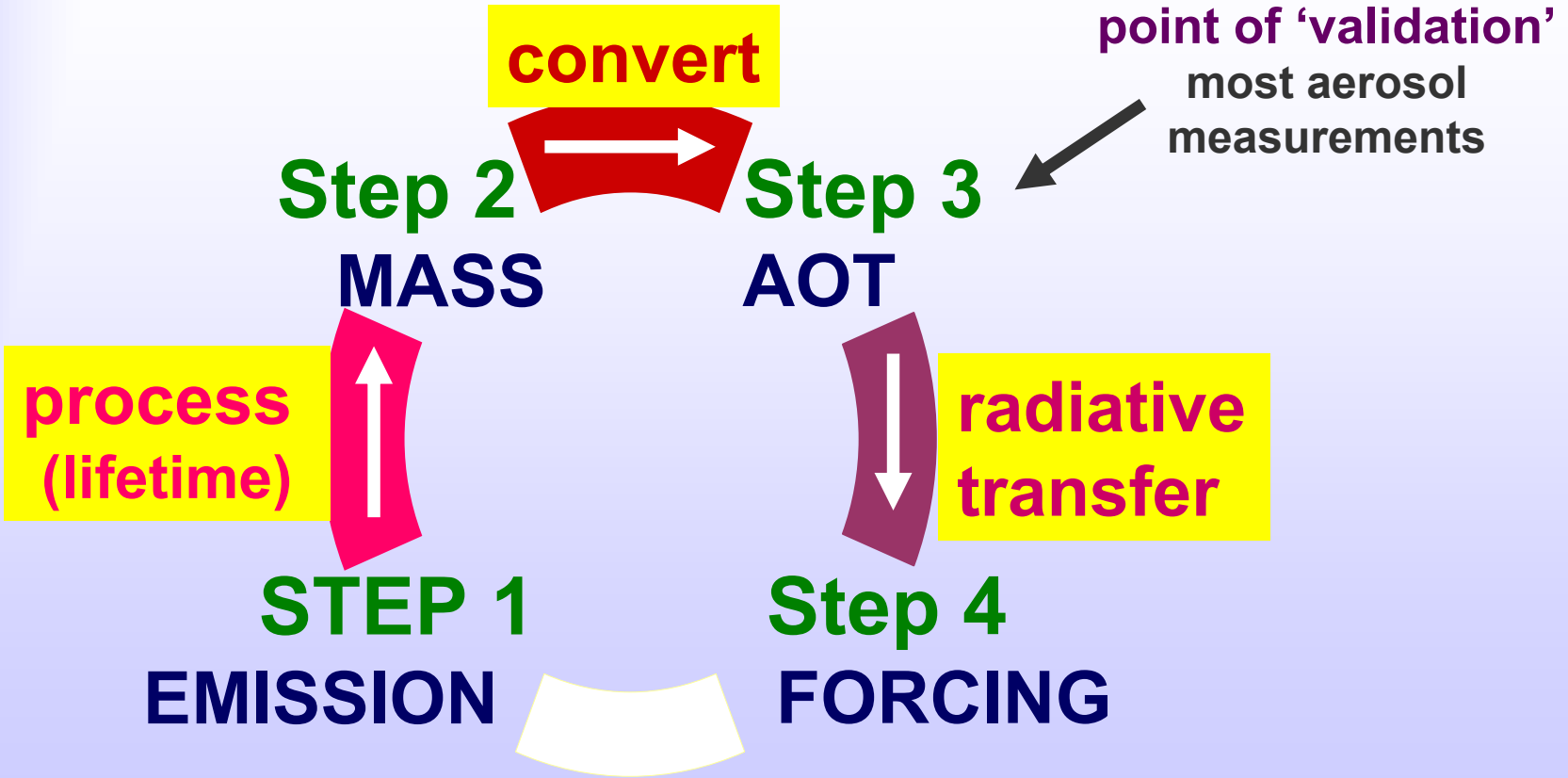
Aerosol – Climate - Modeling

- the Earth's **climate is a global issue**
- 'global' **aerosol is complex** *(variable by region, season, year)*
  - **concentration (aot ⇨)**
  - **absorption**
  - **size**



MODIS/ MISR 2001 composite ⇨
for seasonal aerosol optical depth

Aerosol Modeling
a 4 STEP process



Modeling: OLD vs. NEW

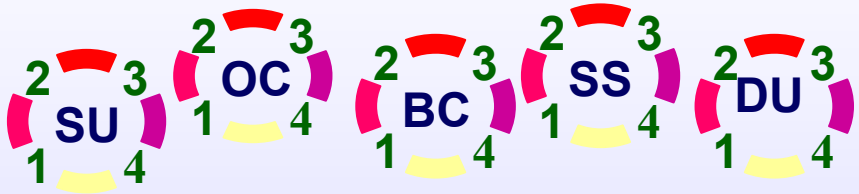
OLD

- aerosol = sulfate

  - low absorption
  - focus on industry
  - globally incomplete

NEW

- aerosol = many types



  - better characterization
  - more processes

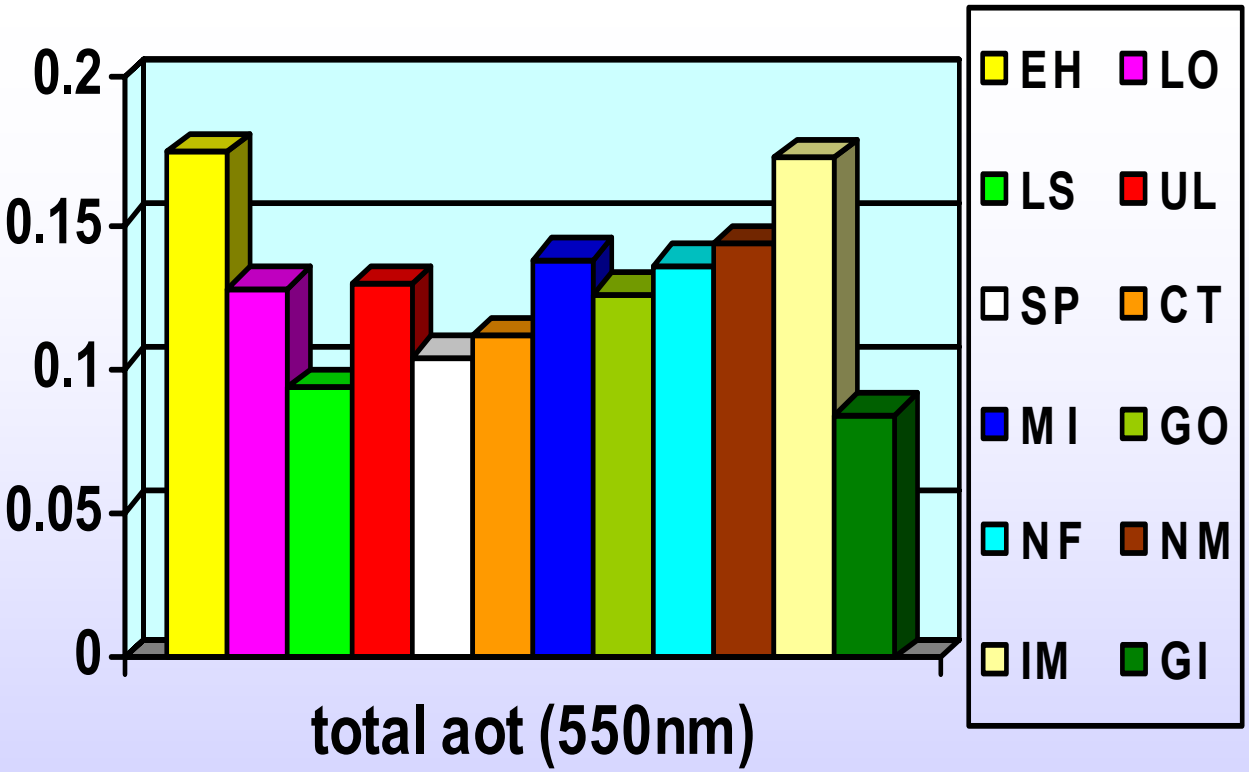
⇨ more errors ?!

despite better representation in new aerosol modules
… the associated climate uncertainties remain large !

aerosol optical depth (STEP 3)

12 models

simulated global yearly averages for the visible aerosol optical depth (aot)



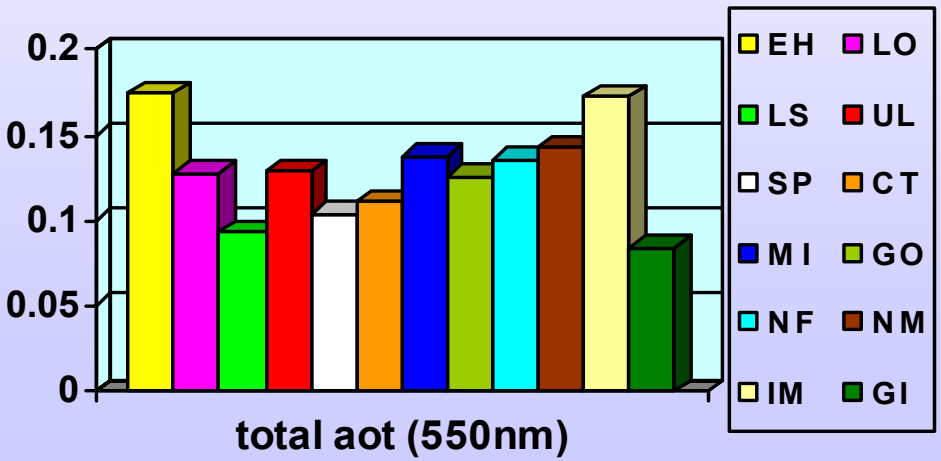
- modeled global yearly averages are similar
- so let us look at details behind differences

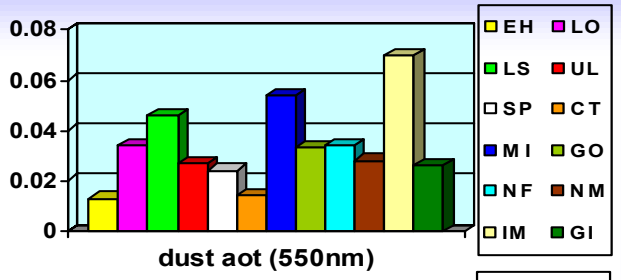
opt. depth (STEP 3)

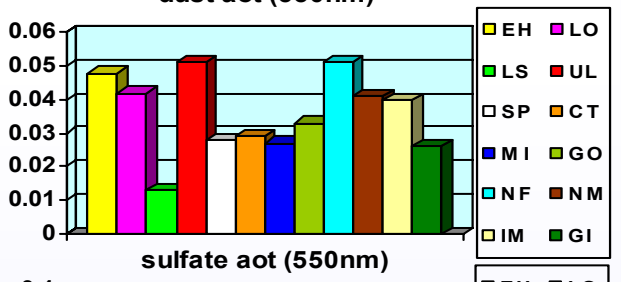
by type ⇨

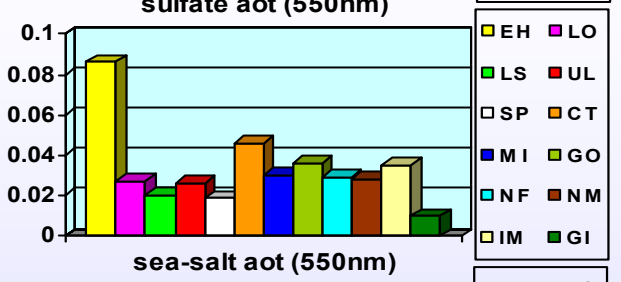
- notice the different ‘make-up’
  - different properties mean
    - differences in size (e.g. water uptake)
    - differences in absorption

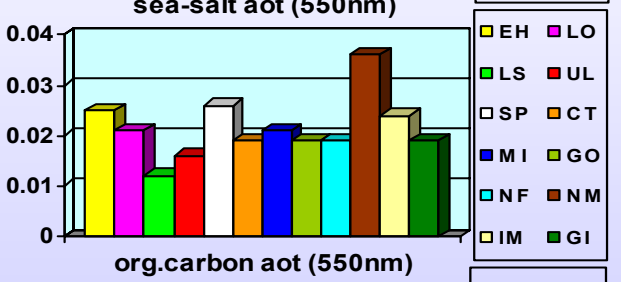
    ⇨ differences in aerosol forcing !

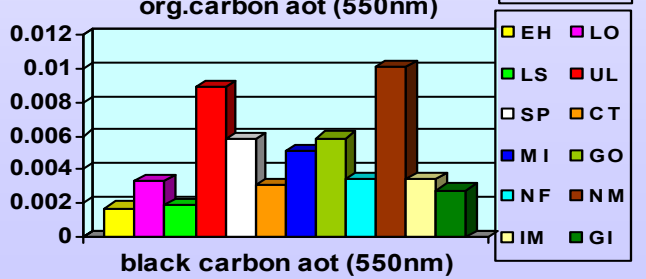






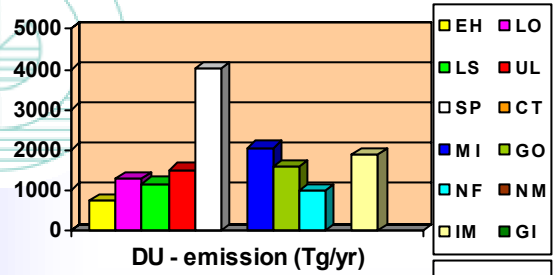


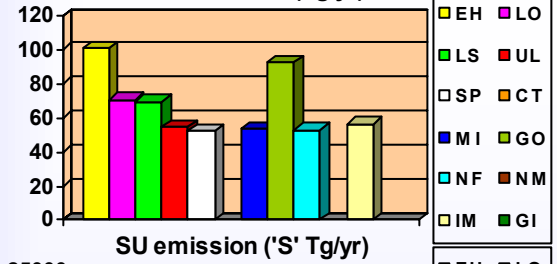


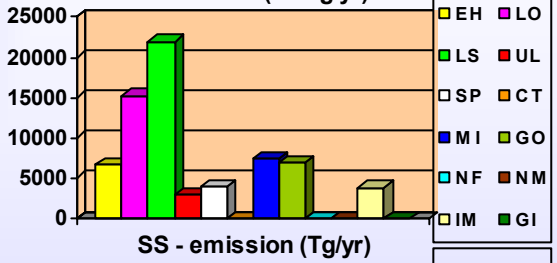


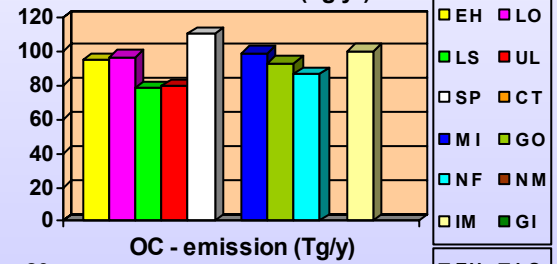
simulated aerosol - by type

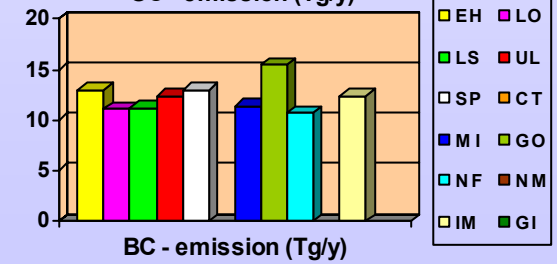
emission

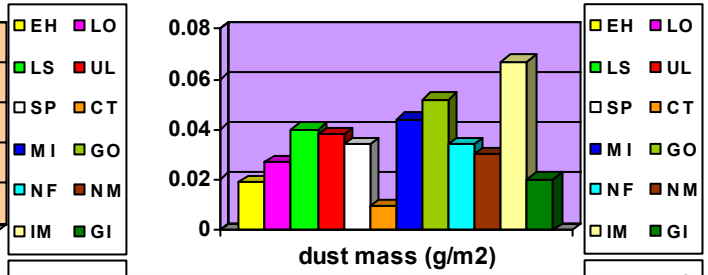




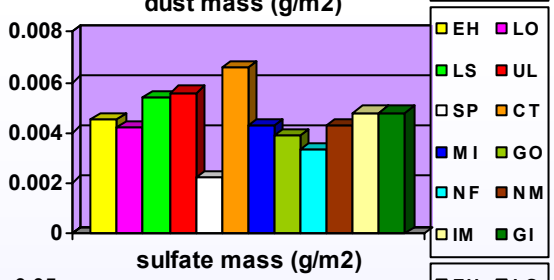


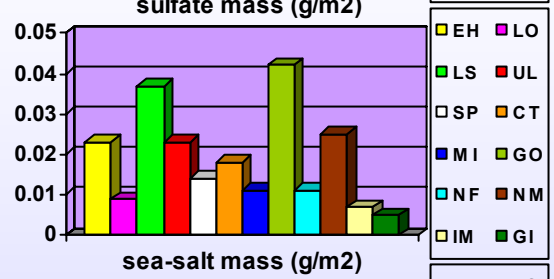


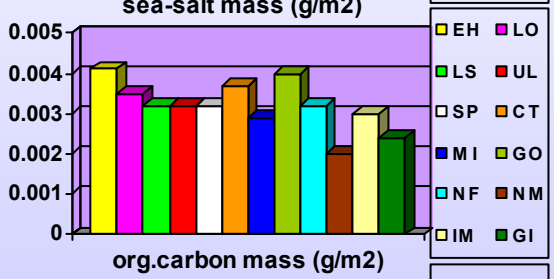


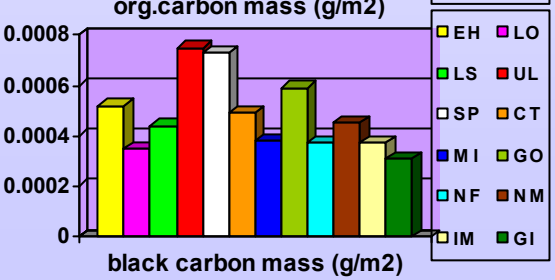


mass

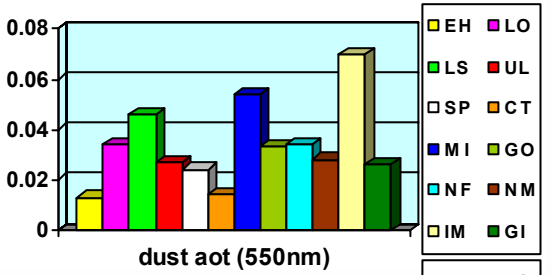


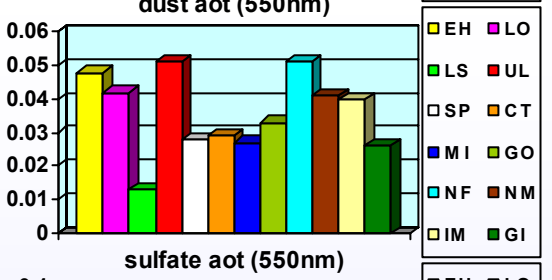


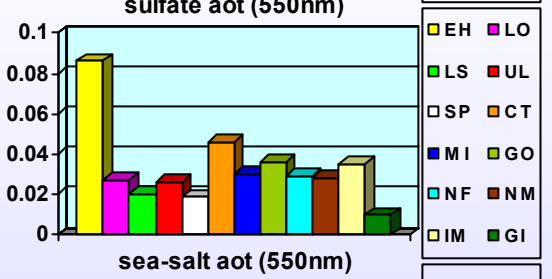


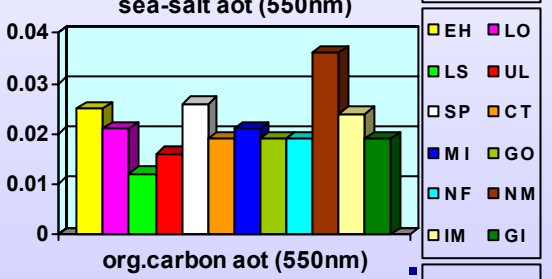


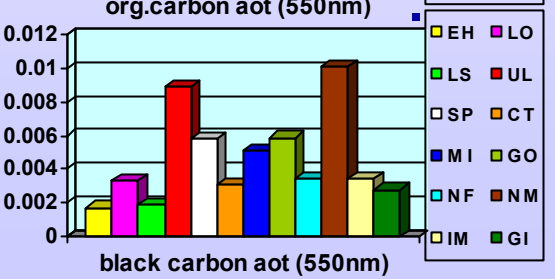
opt. depth











aerosol processing

… by component

Transformation

in 12 diff. component aerosol modules in global modeling

lifetime

STEP 1 ⇨ STEP 2

emission ⇨ mass

mass ext. eff.

STEP 2 ⇨ STEP 3

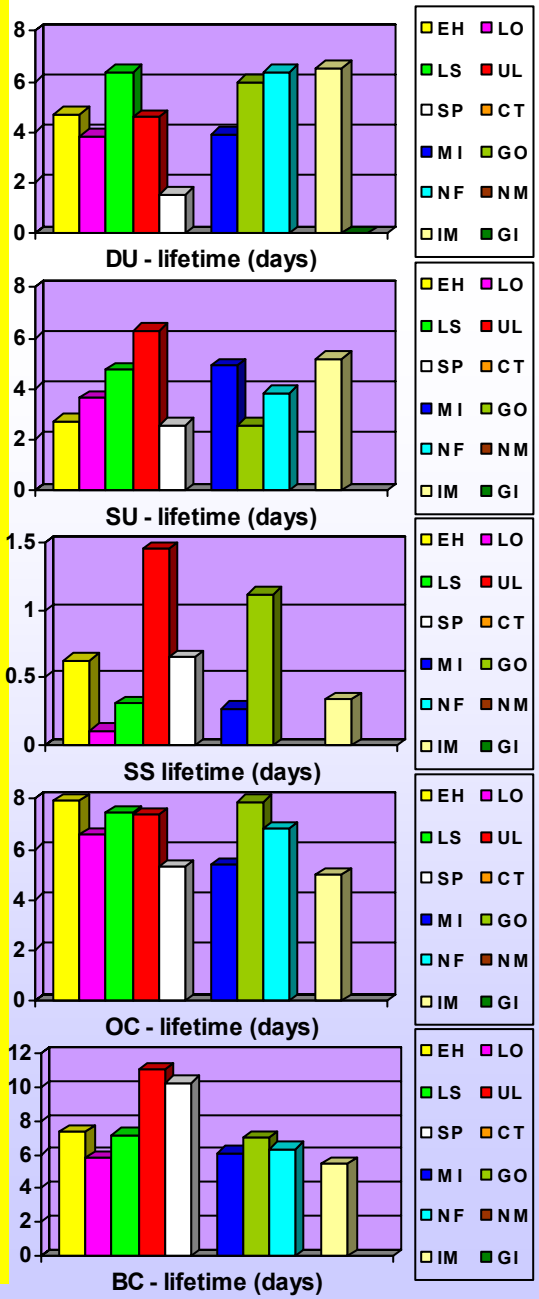
mass ⇨ opt.depth

STEP 1 EMISSION

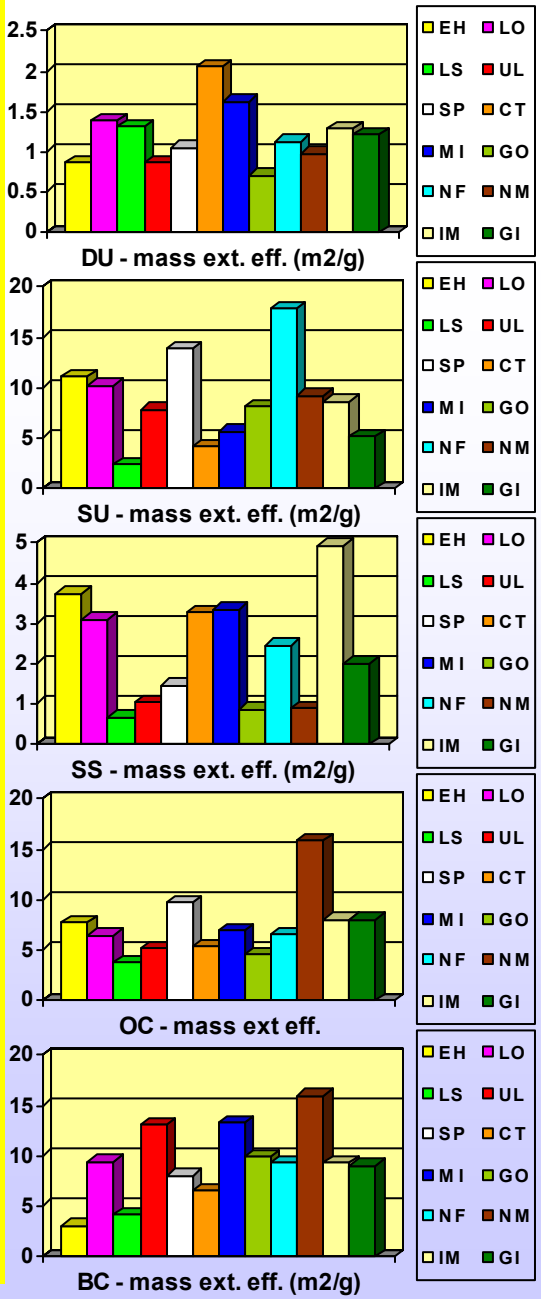
STEP 2 MASS

STEP 3 AOT

lifetime *(days)*



mass ext. eff. *(m2/g)*



first impressions

- despite similar yearly global ‘aot’ totals there are
  - significant differences in aerosol composition *also from*
  - significant differences in component processing

  ⇨*large differences on regional and seasonal scales !*

  ⇨*‘modeling skill’ could be based on offsetting errors*

- aot evaluations tell only part of the story
  - but data-sets are available for aot …

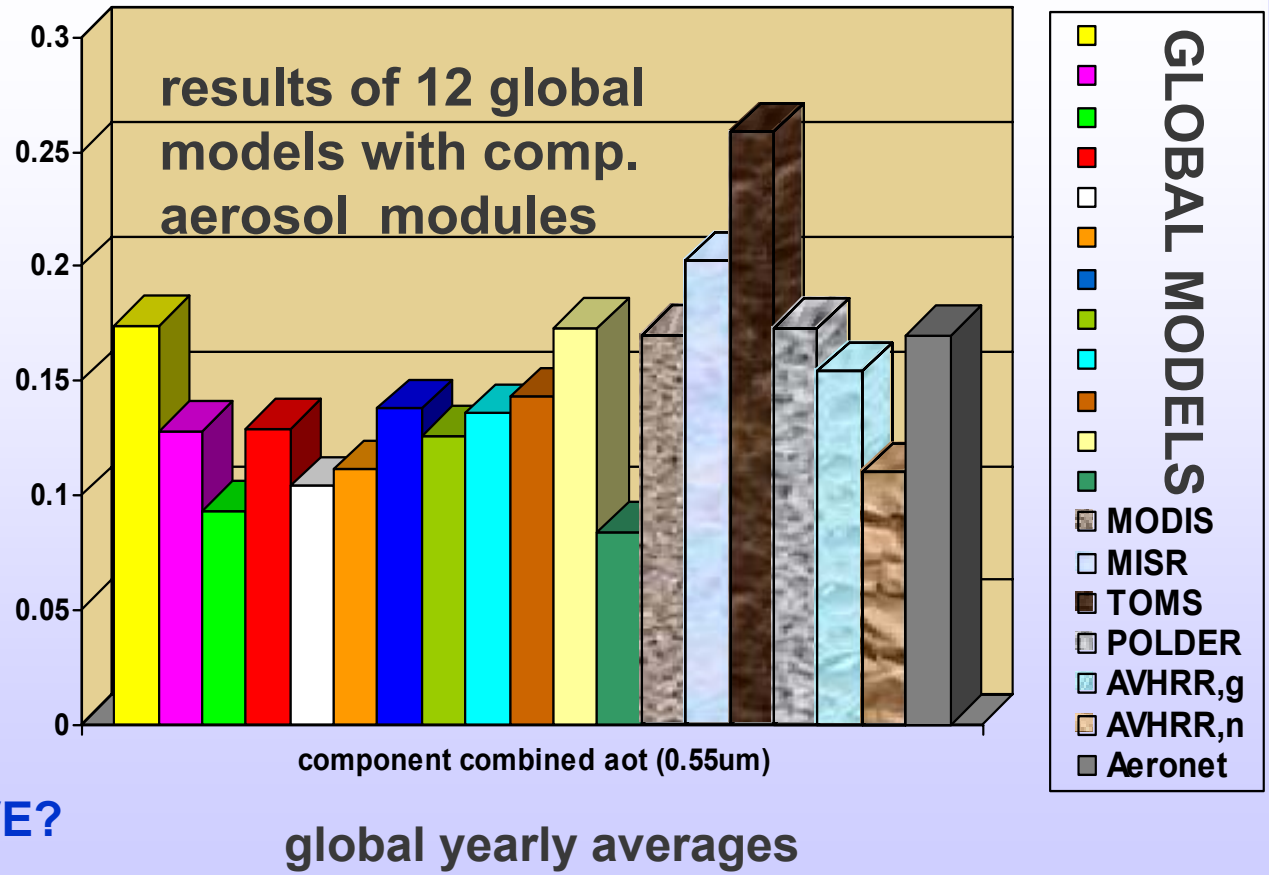
- consistency / sensitivity tests are needed to clarify issues in aerosol processing
  - Experiment B: prescribe emission sources for models

aot datasets for evaluations

- **global available data** (suggest that most models underestimate 'aot')
  - Satellite Data
    - AVHRR
    - TOMS
    - POLDER
    - MODIS
    - MISR
    - composite

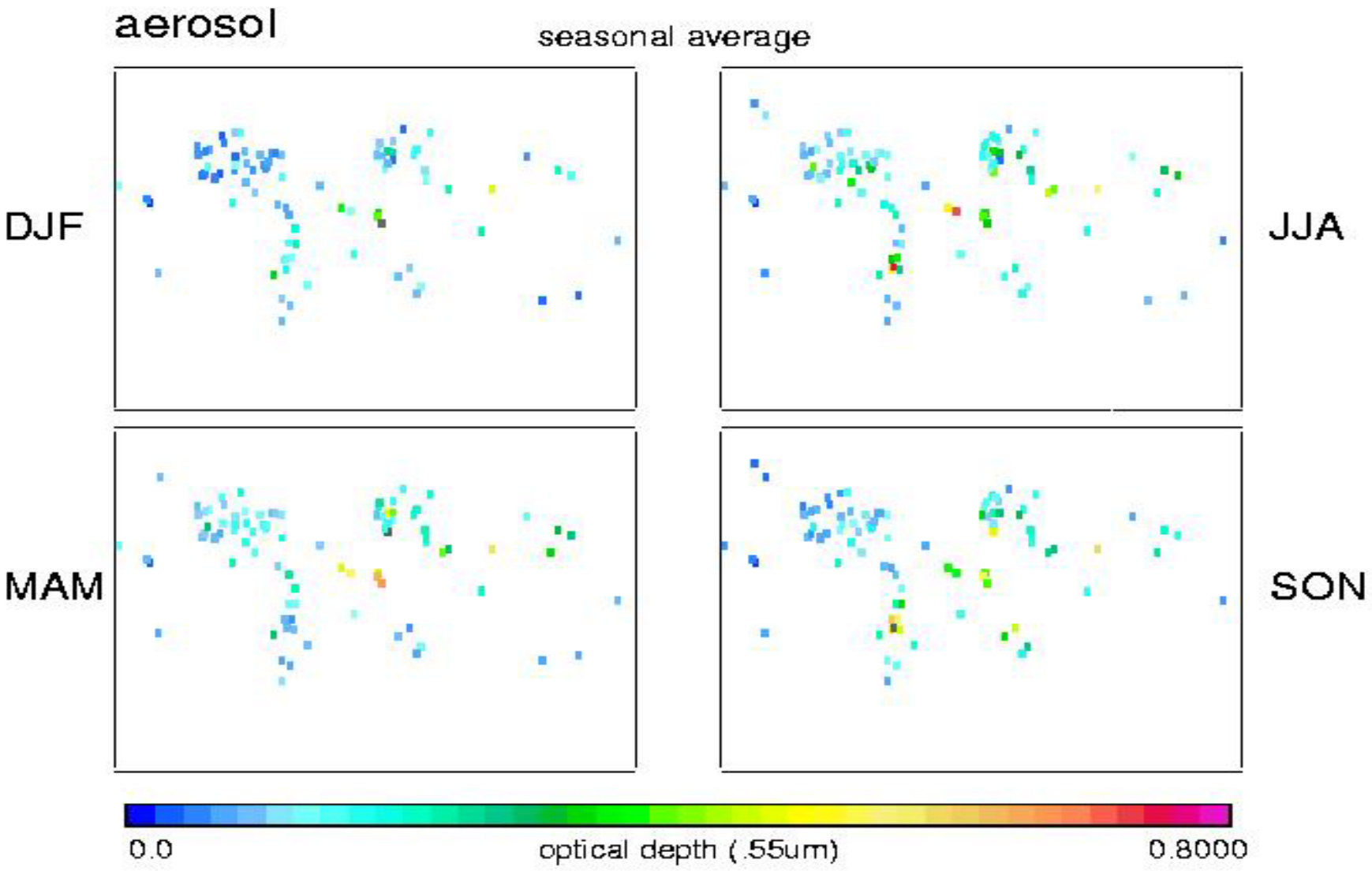
    WHAT TO USE?
  - AERONET

    IS SAMPLING REGIONAL REPRESENTATIVE?



global yearly averages

aot *seasonal AERONET data*



global fields of monthly

aot deviations

of an average models

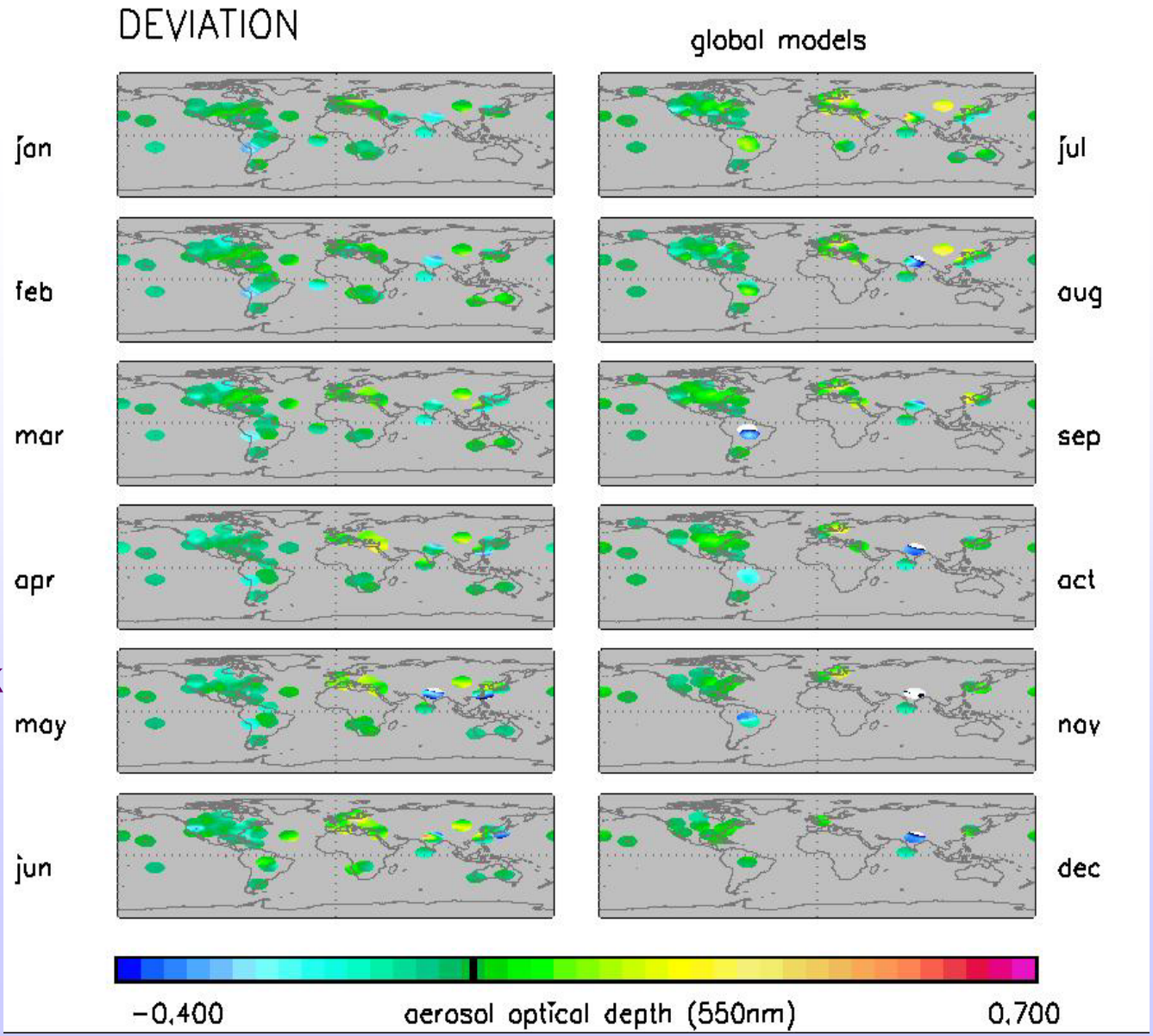
with respect to

AERONET data

← model too small ← zero → model too large → → → →

aot *('average model' – AERONET)*

- blue
  - simulations too small
- yellow / red
  - simulations too large
- discrepancies
  - biomass peak
  - Euro summer
  - Asian dust



global fields of seasonal

aot deviations

of individual models

with respect to

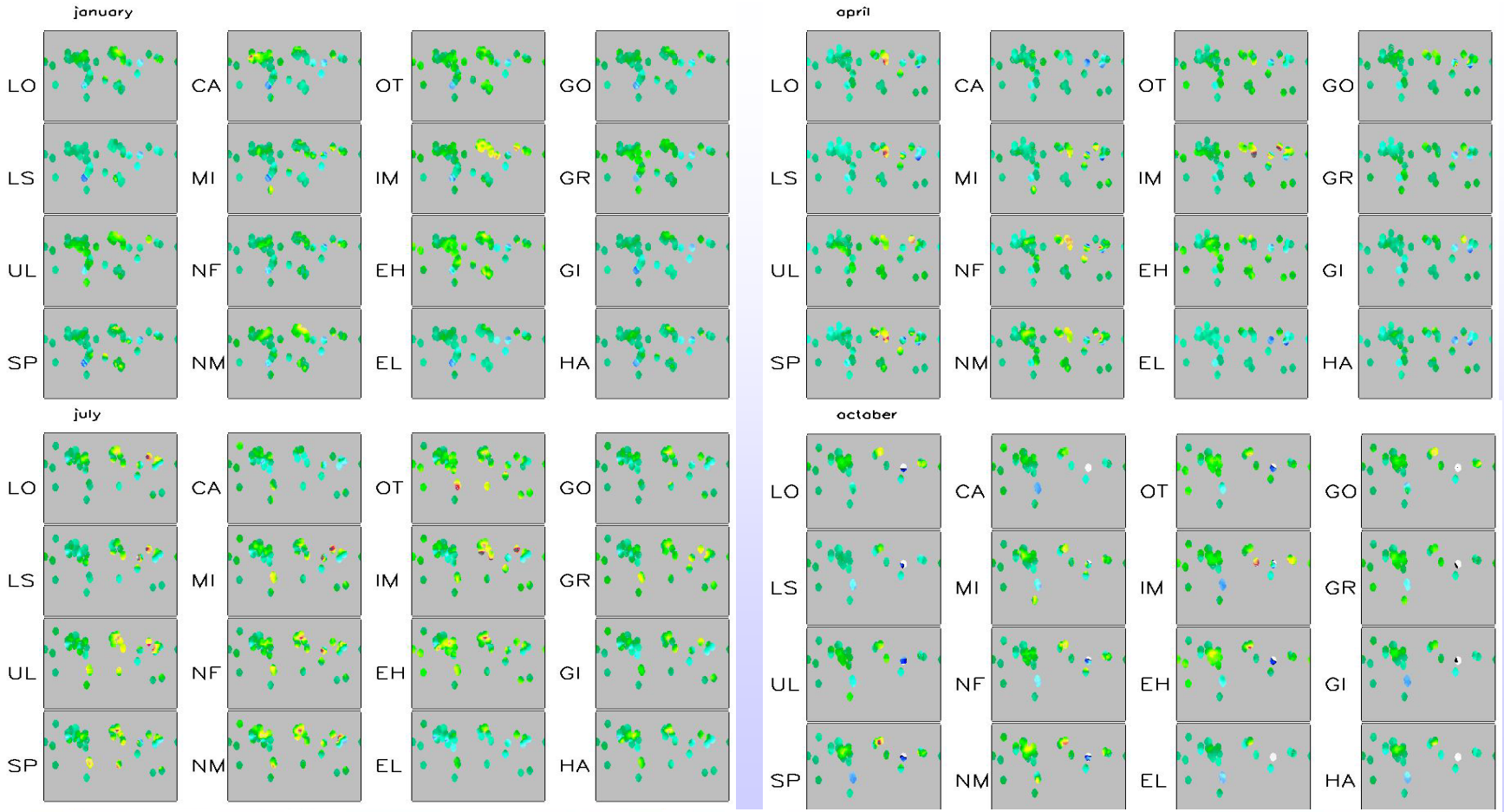
AERONET data

← model too small ← zero → model too large → → → →

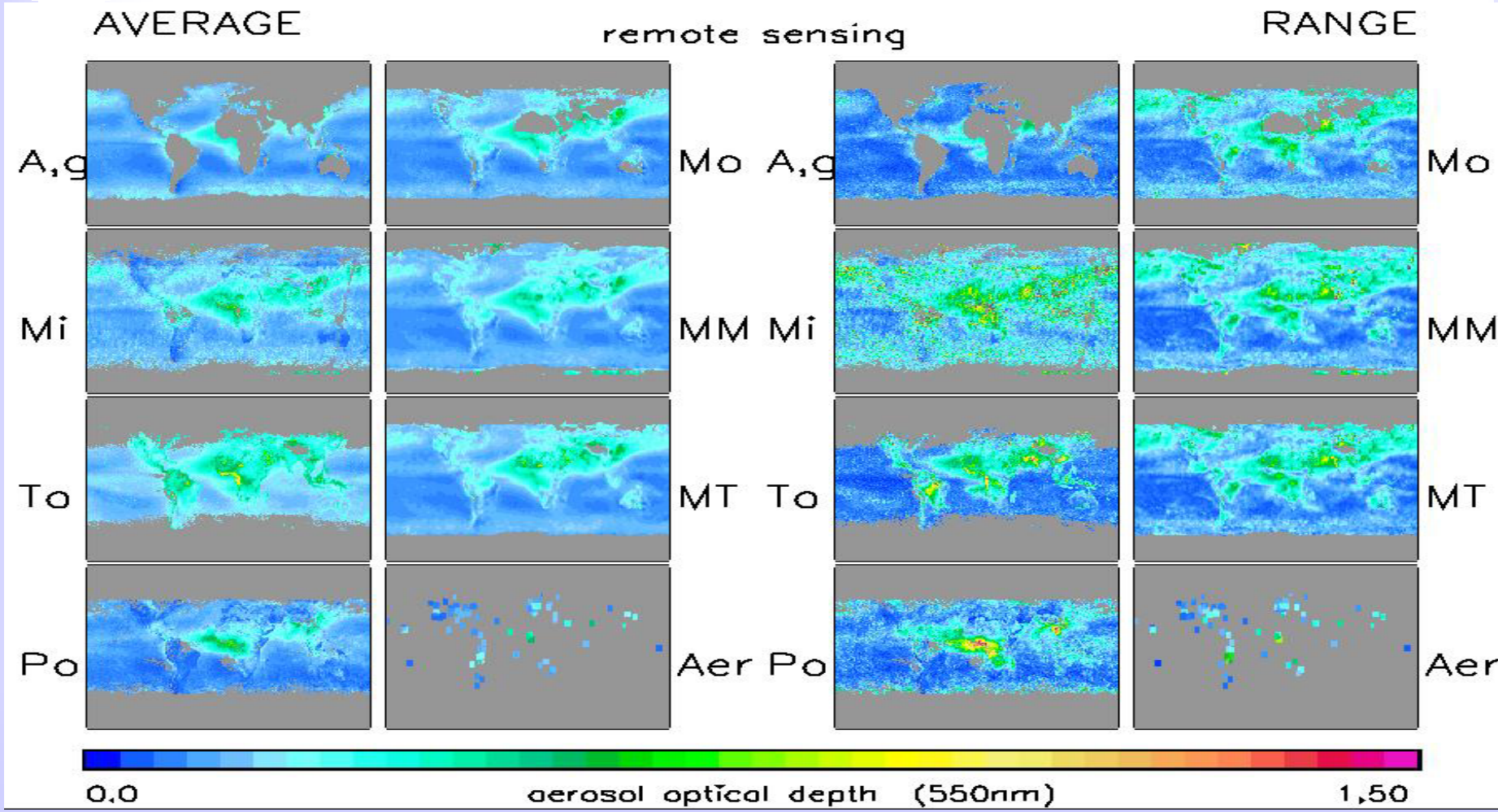
aot *(individual models – AERONET)*

– many non-green colors = larger discrepancies

(…but regional non-representation has NOT been filtered)

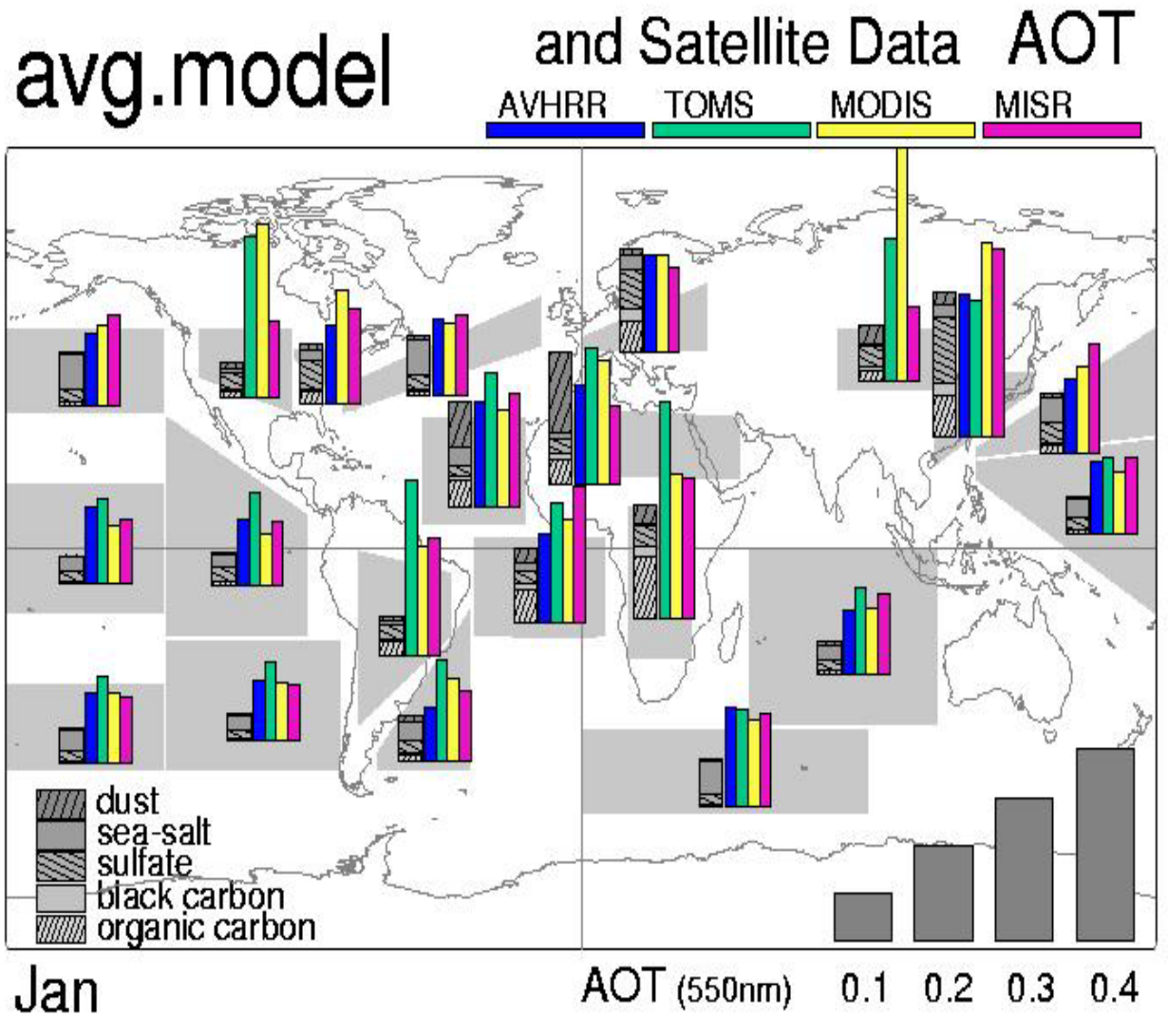


aot *Satellite Data*



- **choice: MODIS complemented by MISR (MM)**

aot *(average model vs multi-year satellite data (AVHRR, TOMS) vs year 2001 satellite data (MODIS, MISR)*



MODEL- DATA

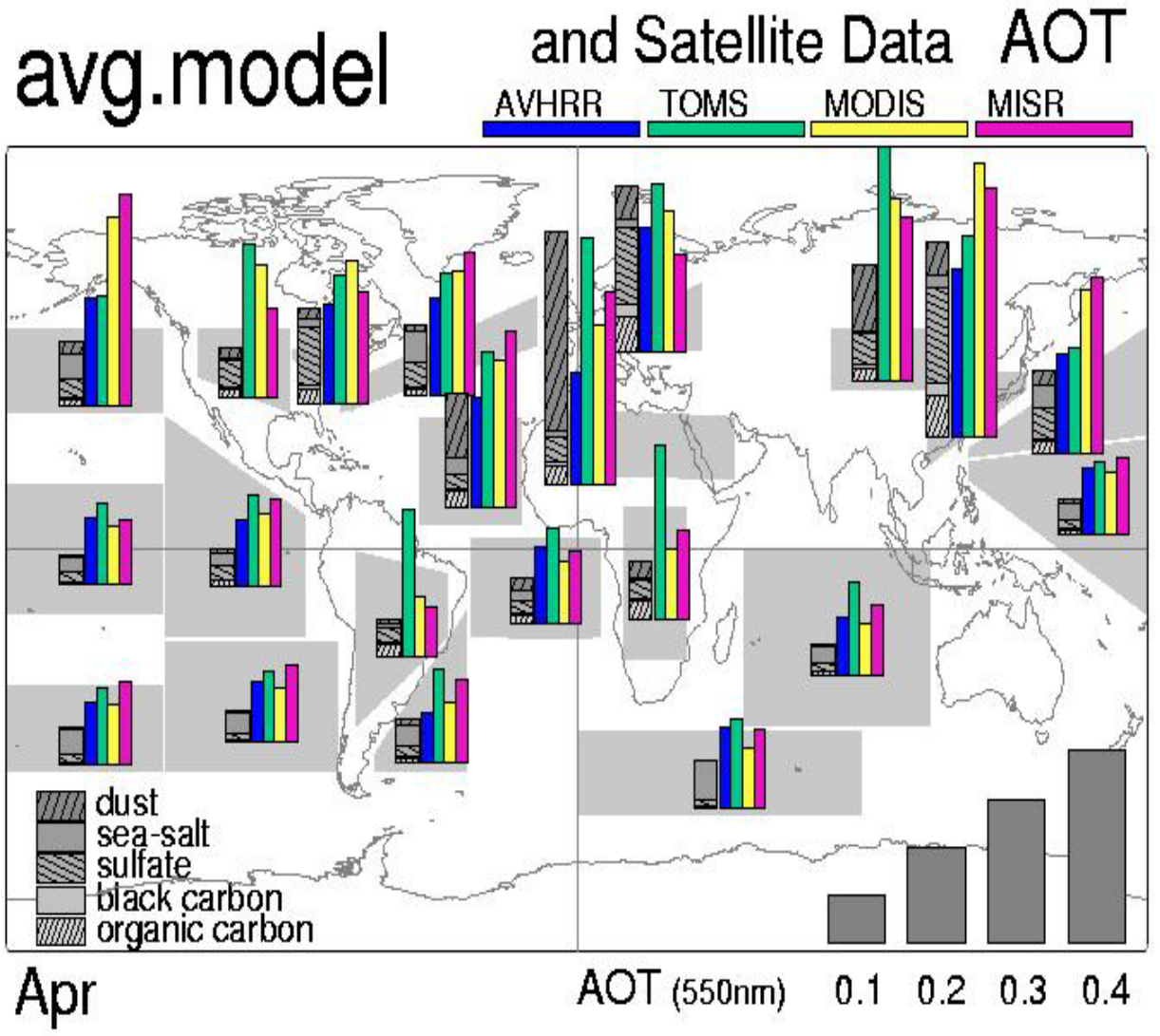
simulations suggest smaller 'AOT' than satellite retrievals

→ in remote regions ! (transport? sources?)

note: extreme satellite data at high latitude winters are in error → sub-pixel snow ground cover

MODIS, MISR→ year 2001
AVHRR, TOMS → multi-yr

aot *(average model vs multi-year satellite data (AVHRR, TOMS) vs year 2001 satellite data (MODIS, MISR)*



best AOT retrieval

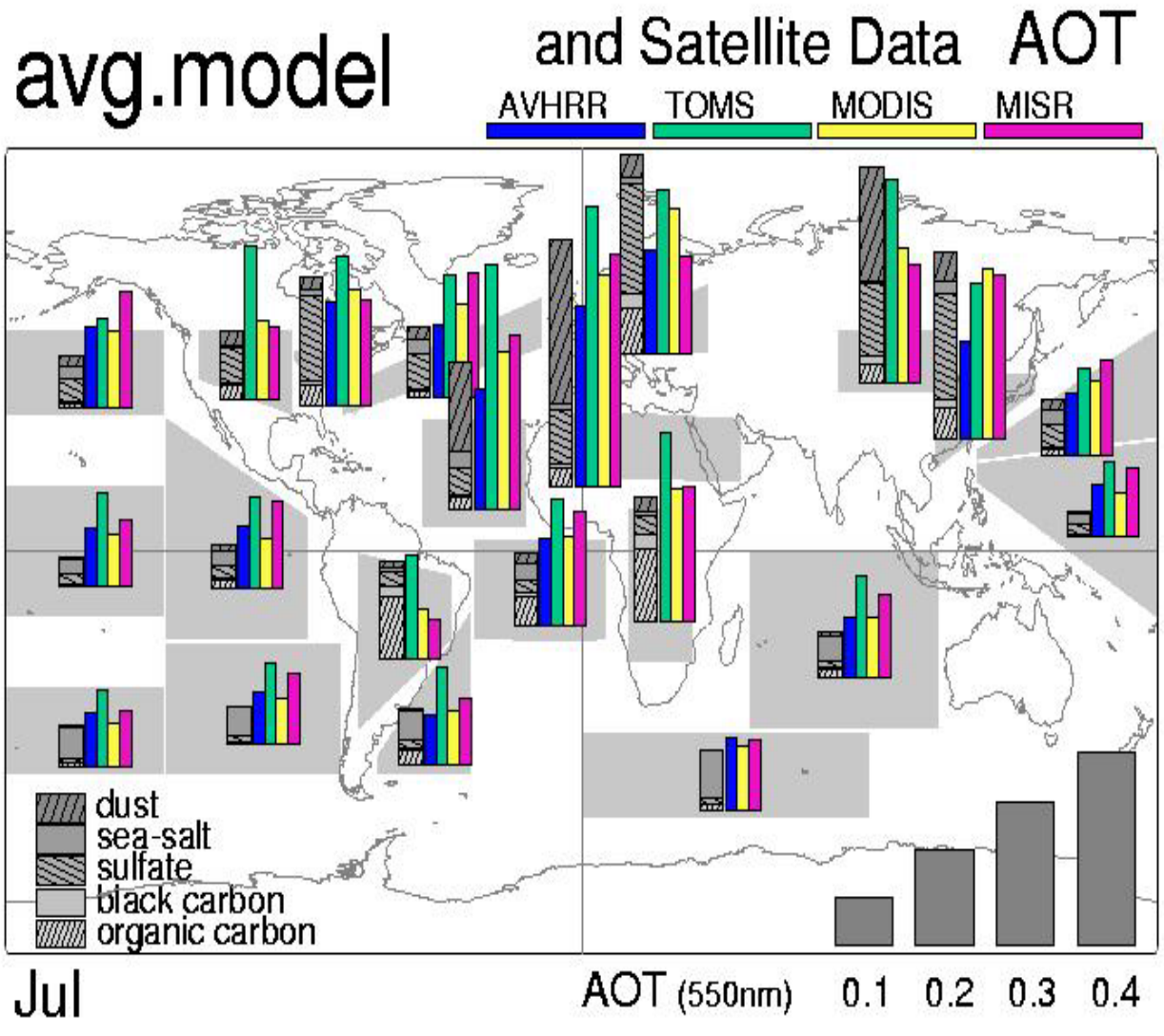
over ocean: MODIS

→ best cloud detection (using 250m pixels) thus less pot. contamination
→ lowest ocean aot
(but still up to twice as large than simulations)

note: an unusual trend [MODIS >TOMS, AVHRR] off-Asia … because 2001 had unusual strong dust transports from Asia

MODIS, MISR→ year 2001
AVHRR, TOMS → multi-yr

aot *(average model vs multi-year satellite data (AVHRR, TOMS) vs year 2001 satellite data (MODIS, MISR)*



best AOT retrieval

over land: ?

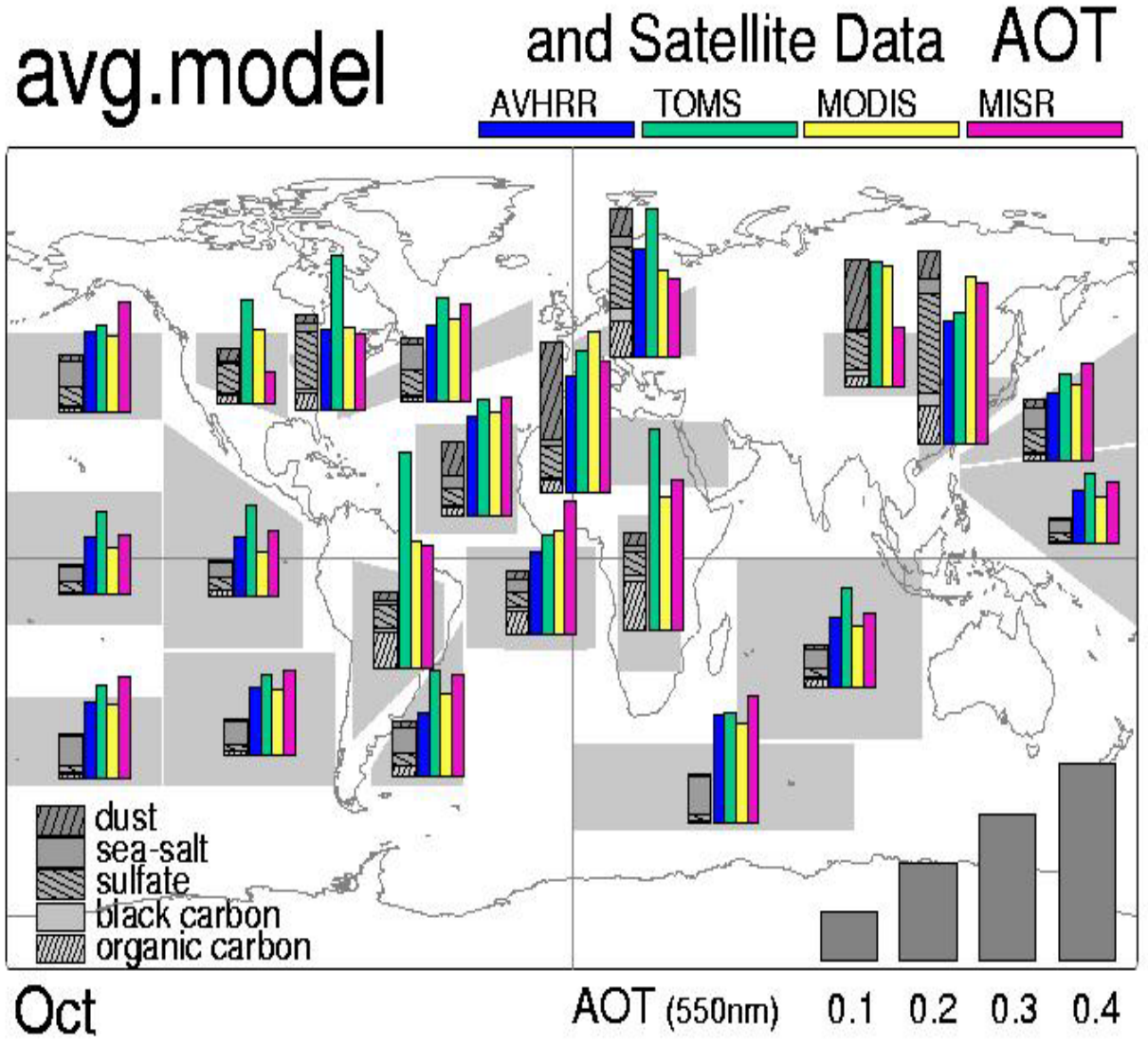
TOMS: biased high
MODIS incompl. cover
MISR: temp. sparse

MODIS/MISR combo?

note: MISR *(with a more complete spat. coverage than MODIS)* suggests smaller (!) optical depths over urban regions → smaller sizes?

MODIS, MISR→ year 2001
AVHRR, TOMS → multi-yr

aot *(average model vs multi-year satellite data (AVHRR, TOMS) vs year 2001 satellite data (MODIS, MISR)*



SEASONLITY

both – simulations and retrievals underestimate seasonality compared to ground data statistics e.g. biomass maxima in tropics too weak (from Aug-Nov in S.Ame/S.Afr)

note: summer / fall simulations exceed satellite data near urban sources (outdated inventories?)

MODIS, MISR→ year 2001
AVHRR, TOMS → multi-yr

global fields of seasonal

aot deviations

of global satellite data-sets

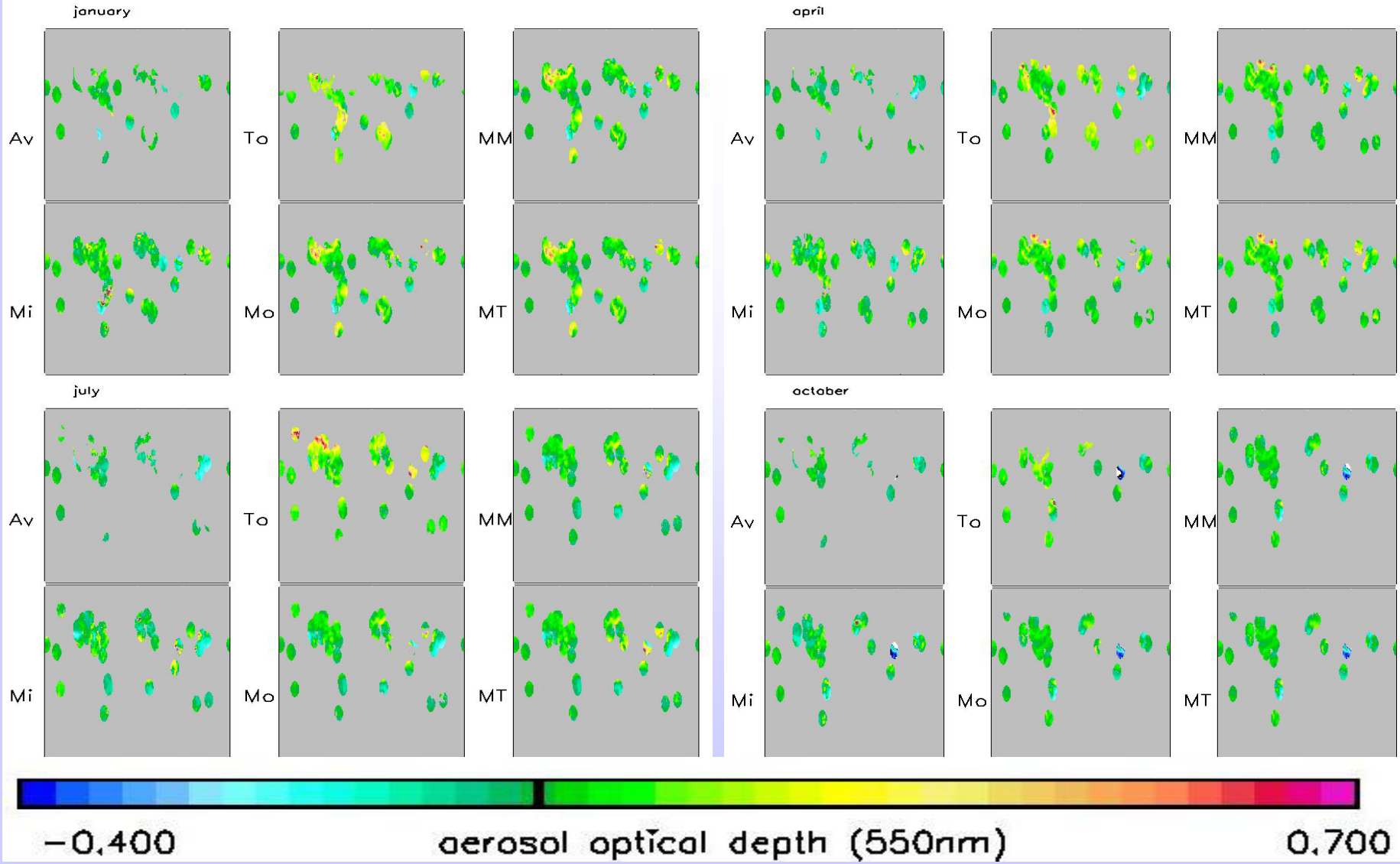
with respect to

AERONET data

← model too small ← zero → model too large → → → →

aot *(Satellite data – AERONET)*

significant differences to AERONET (even for MODIS/MISR choice)



global fields of seasonal

aot deviations

of individual models

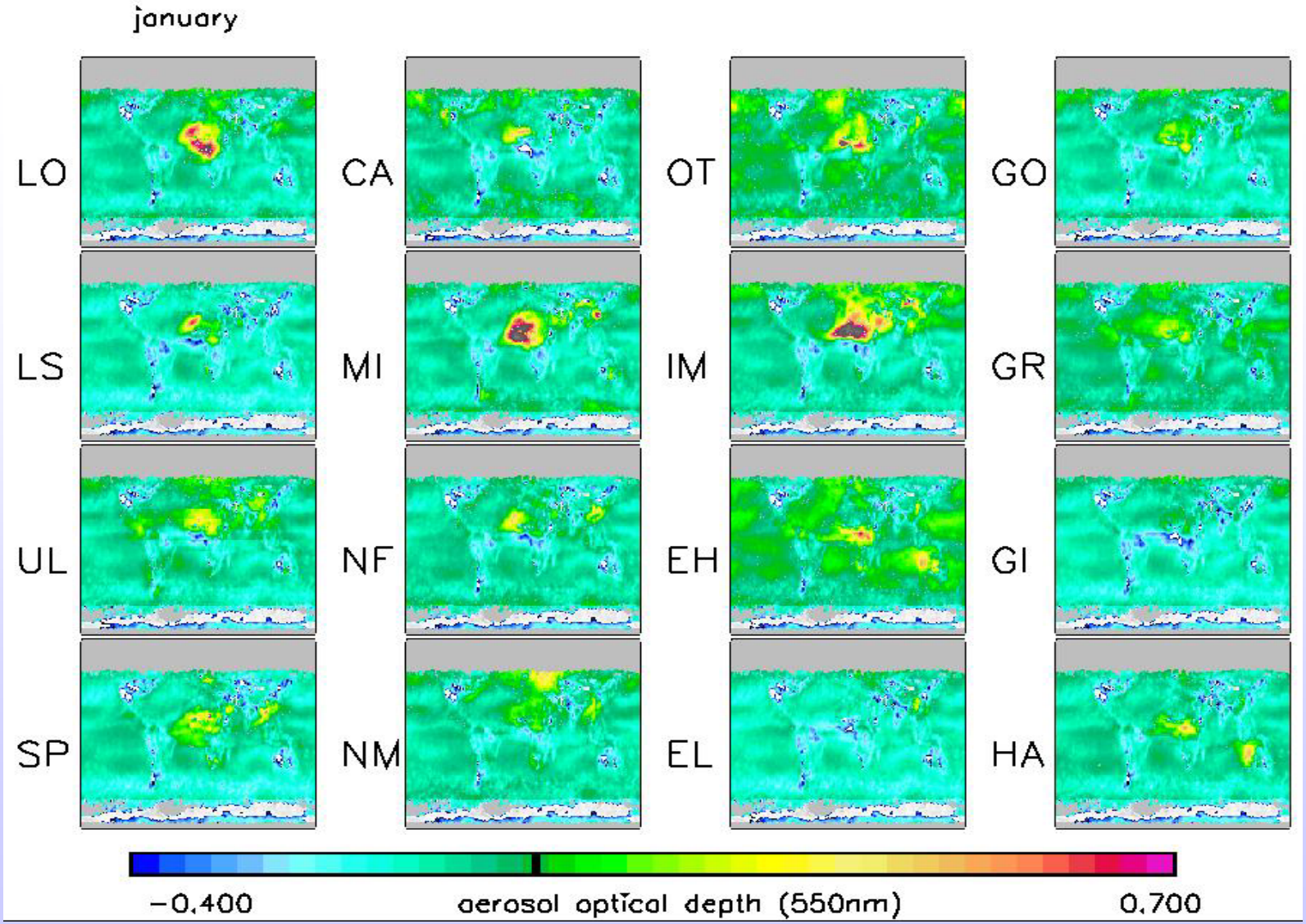
with respect to

MODIS/MISR 2001 data

← model too small ← **zero** → model too large → → → →

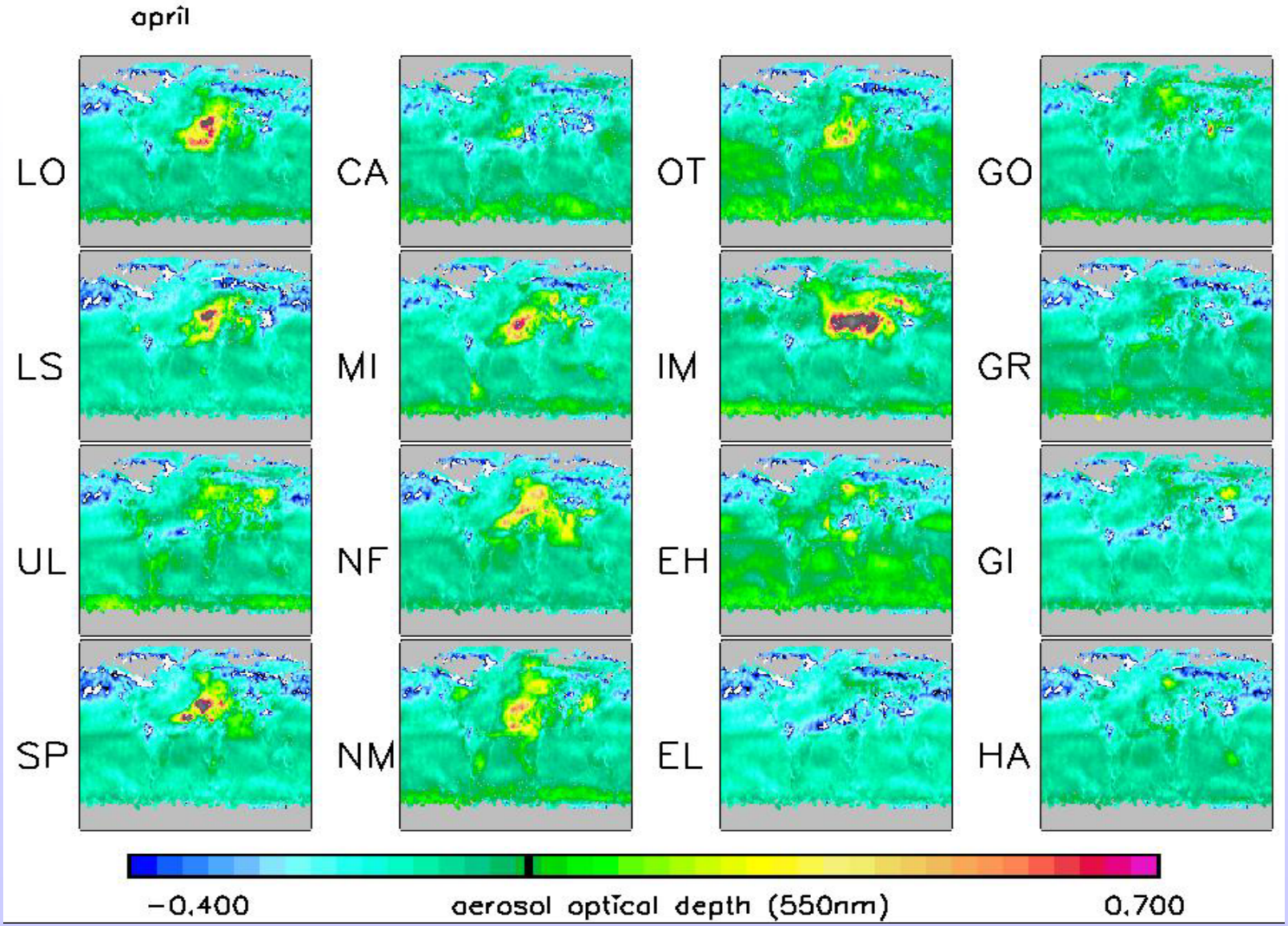
aot *(indiv.models - MODIS/MISR 2001)*

- Jan



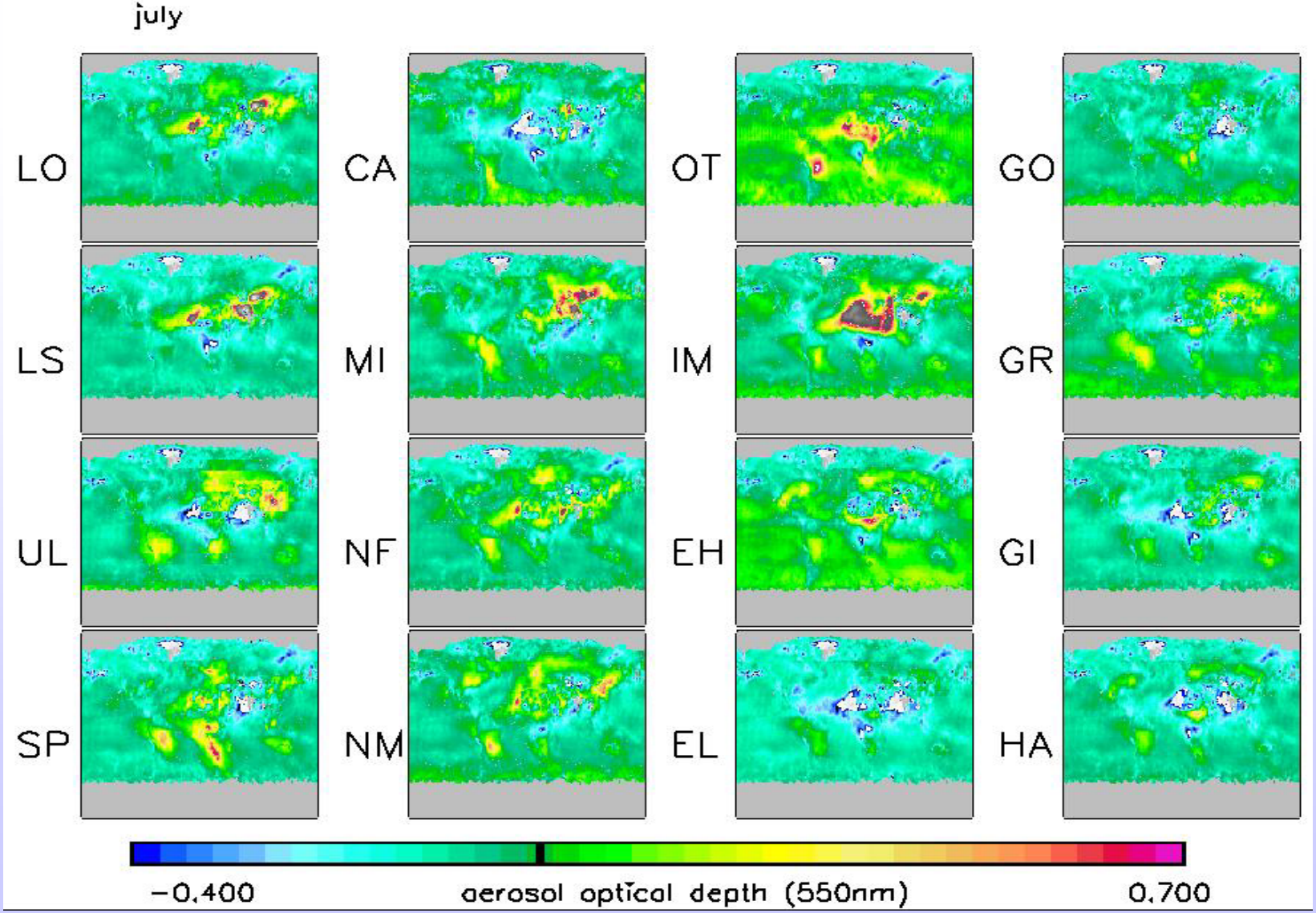
aot *(indiv.models - MODIS/MISR 2001)*

- **Apr**



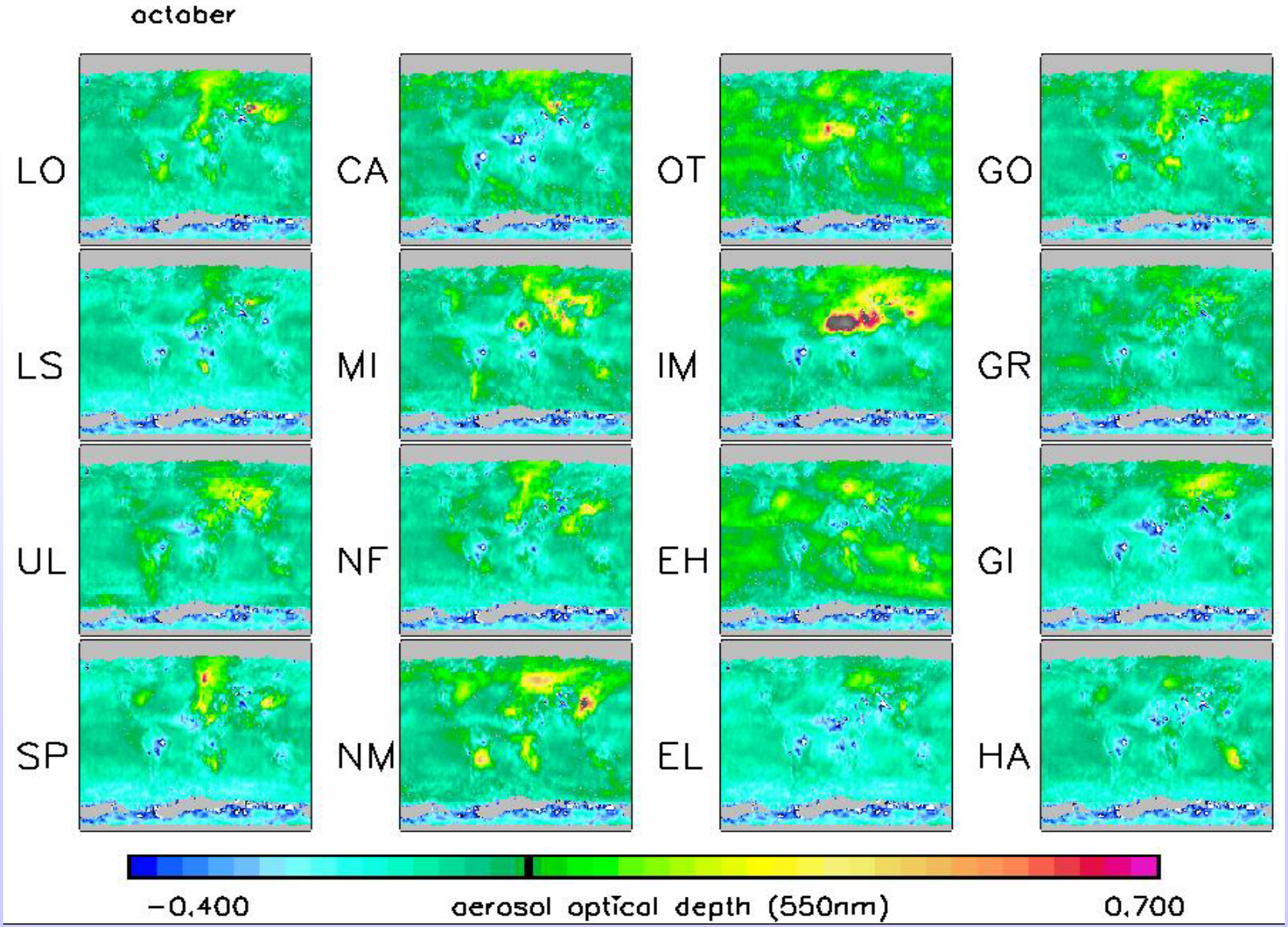
aot *(indiv.models - MODIS/MISR 2001)*

- **Jul**



aot *(indiv.models - MODIS/MISR 2001)*

- Oct



final remarks

- optical depth data are an insufficient benchmark when evaluating aerosol modules in global models
  - a better understanding on the data quality of global or regional aerosol measurements is needed
  - comparisons of simulations to component combined column aerosol data-sets do not tell the entire story
    - strong differences in lifetime and for (mass to optical depth) conversions for all aerosol components (off-setting errors?)
- coordinated sensitivity studies are needed to understand differences in aerosol processing
  - simulations with prescribed emission sources etc.