Satellite based global dust source inventories

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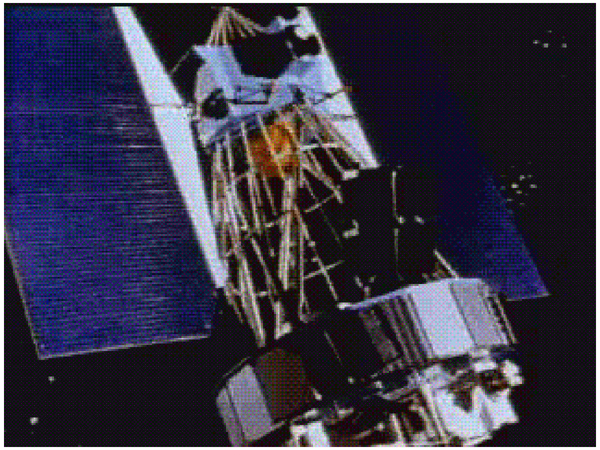
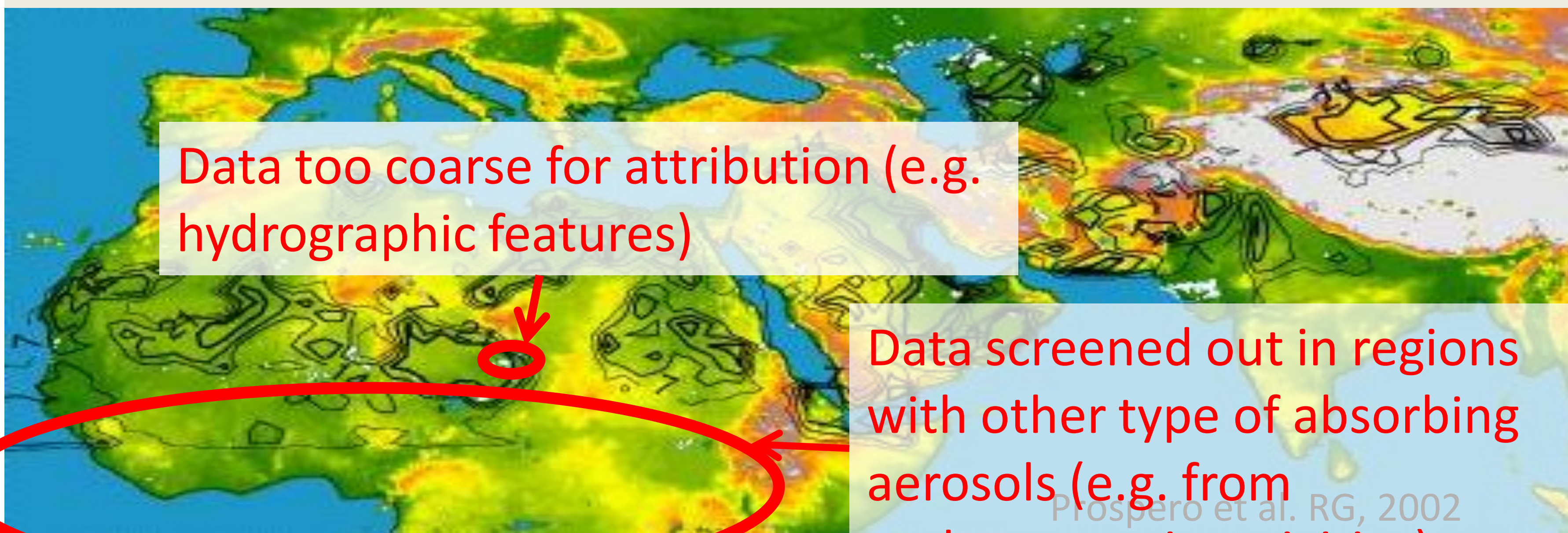


Total Ozone Mapping Spectrometer (TOMS)

$$AI = -100 \left[\log \left(\frac{I_{\lambda}}{I_{\lambda_0}} \right)_{meas} - \log \left(\frac{I_{\lambda}}{I_{\lambda_0}} \right)_{calc} \right]$$

nUV Absorbing Aerosol => TOMS AI > 0

Dust source = maxima of distribution of Frequency Of Occurrence (FOO) TOMS AI > AI_{thresh} (AI_{thresh} = 0.7 West Africa and Central Asia, 0.2 everywhere else)



Data too coarse for attribution (e.g. hydrographic features)

Data screened out in regions with other type of absorbing aerosols (e.g. from anthropogenic activities)

Dust detection from space

Limitations of TOMS AI:
•Presence of absorbing aerosols other than dust
•Dependency on vertical profile
•Coarse resolution

New satellite instruments with multiple channels retrieval (e.g. MISR, MODIS):
•Spectral variation of τ, ω
•Possibility to screen τ, ω for characteristic aerosol properties

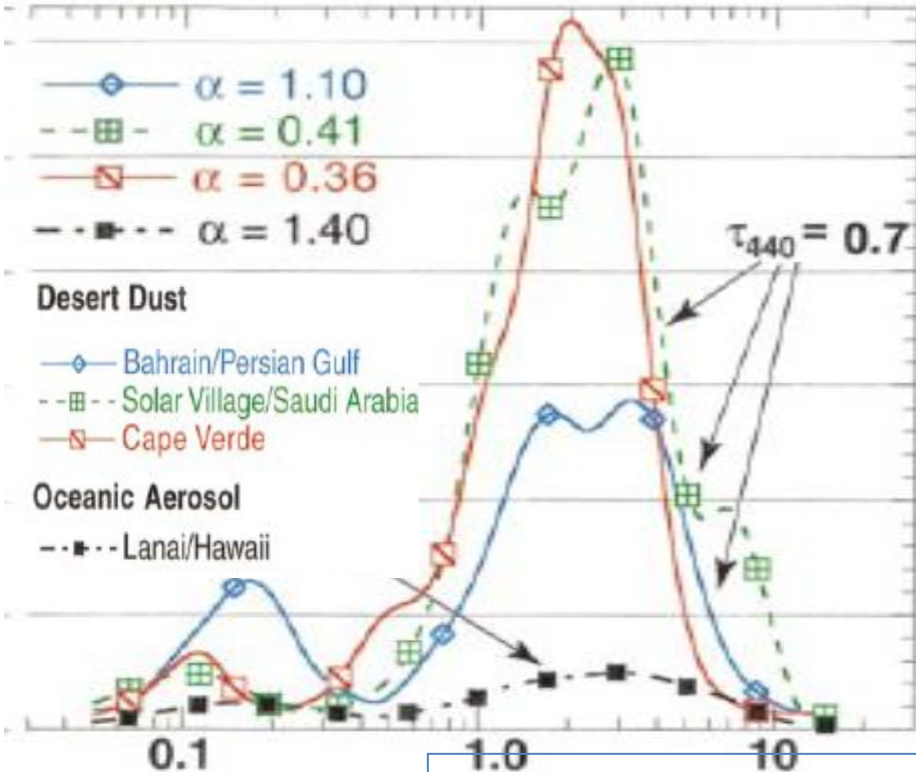
MODIS Deep Blue (Hsu et al., IEEE, 2004, 2006):
•Channels: 412, 470, 670 nm
•Products: τ, ω at 412, 550 an 670nm

Outline

- Dust Optical Depth
  - Screen MODIS DB τ with α and ω to obtain DOD
  - Statistics
- Dust sources
  - FOO of Dust
  - Comparison with TOMS and OMI AI
- Dust emission
  - Comparison with GOCART topographic emission
  - Quantify emission from hydrographic features
  - Quantify emission from land use (“anthropogenic”)

Dust and Angstrom Exponent

Dust size:0.1 to 10 μm radius

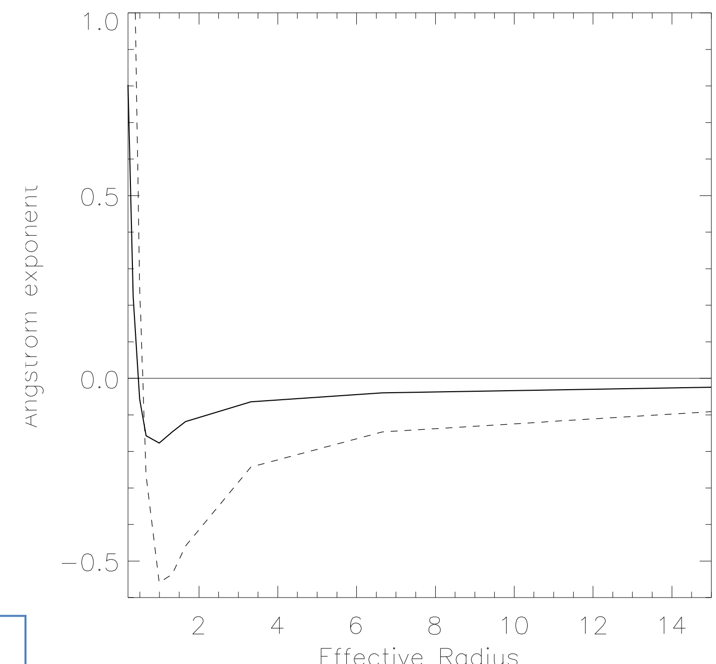


Dubovik et al., JAS, 2002

Assumptions:

Size=lognormal distribution (μ,σ)

m=r+ik from Balkanski et al., ACP, 2007



Angstrom exponent α

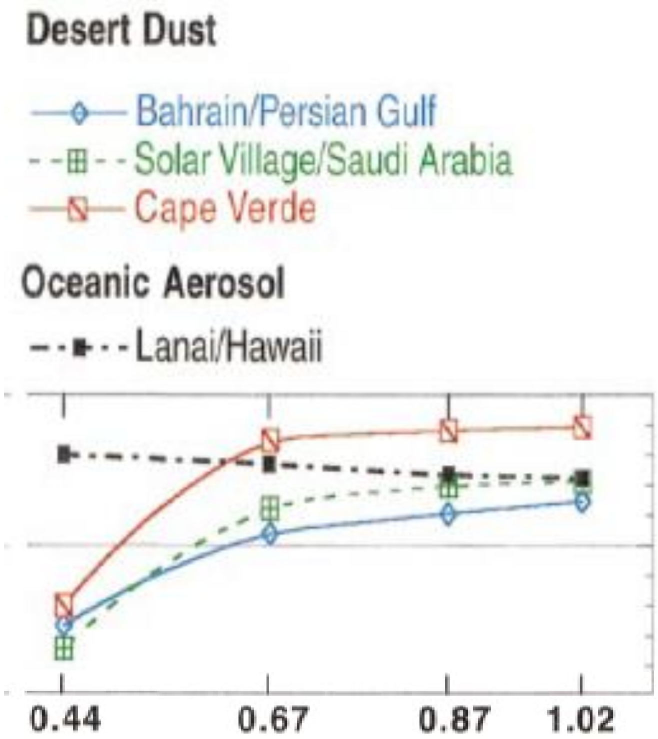
$\alpha = -\log(\tau 1/\tau 2)/\log(\lambda 1/\lambda 2)$

Dusty : $\alpha < 0.5$

Coarse

$\alpha < 0$

Dust and
Spectral Variation of Single Scattering Albedo

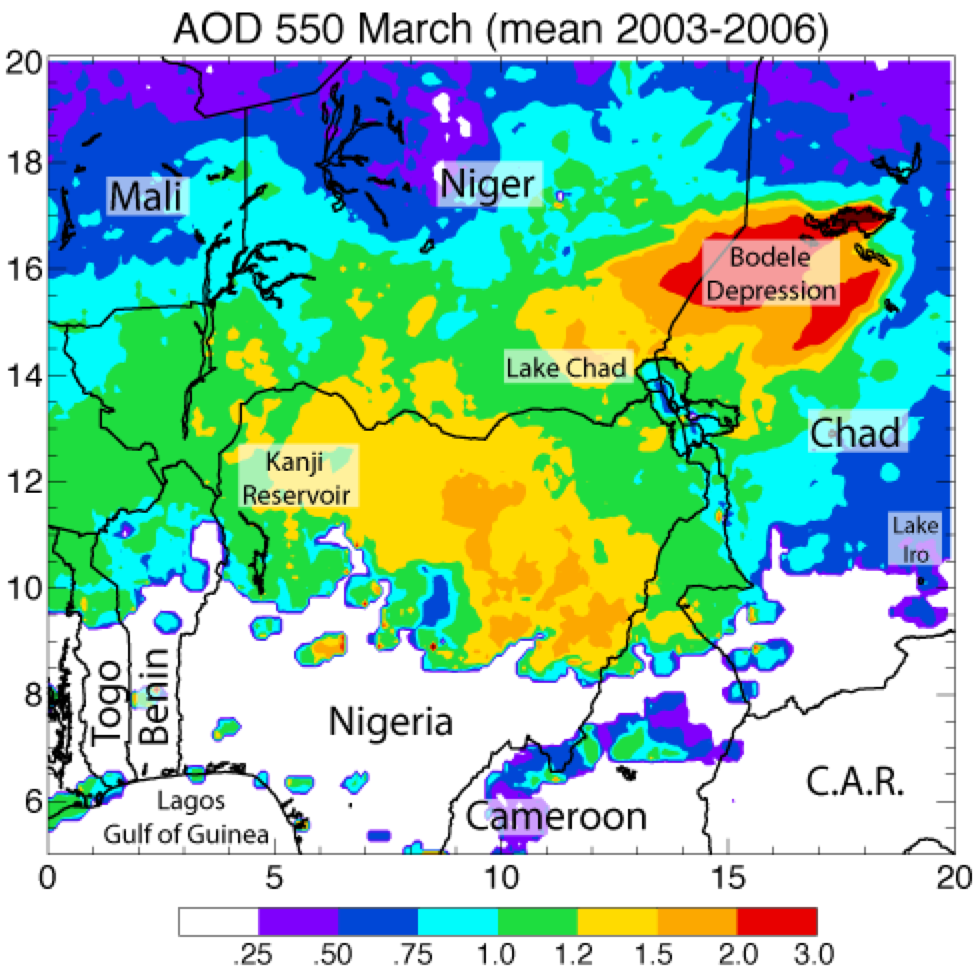


Dust

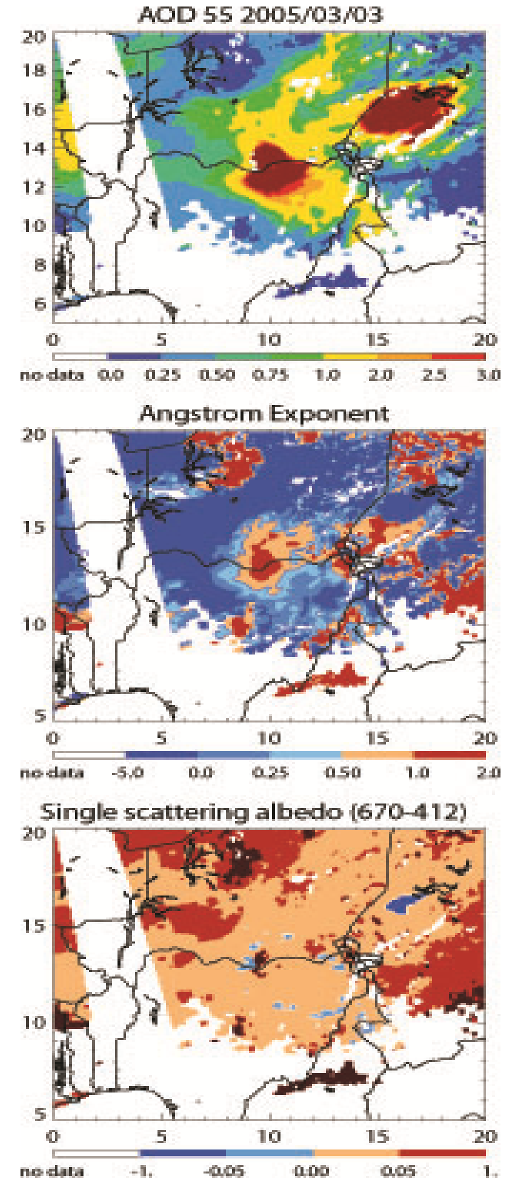
$\omega(\lambda 1)<\omega(\lambda 2)<\omega(\lambda 3)$

$\Delta\omega/\Delta\lambda>0$

MODIS DB Level 2

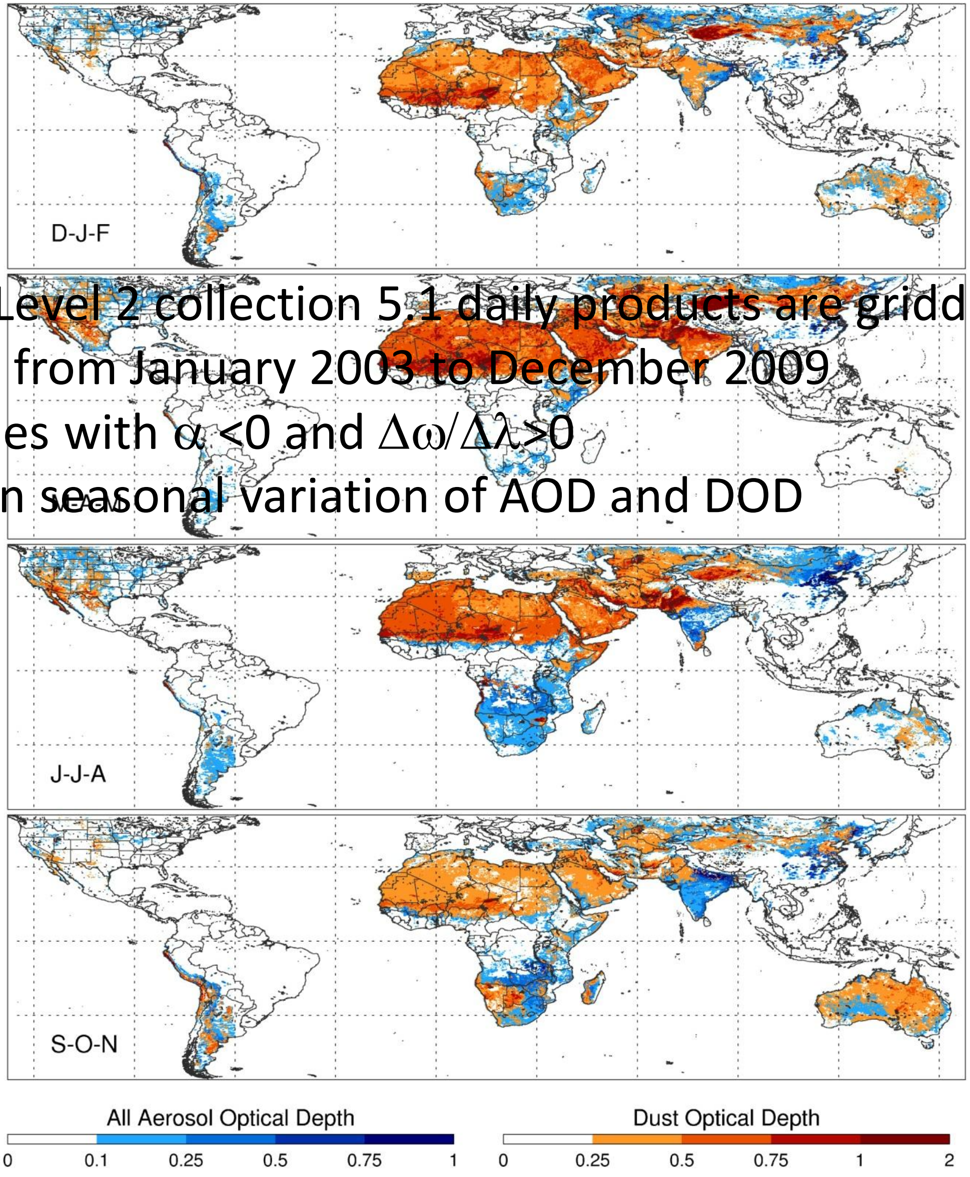


Ginoux et al, JGR, 2010



MODIS DB v5.1 Dust Optical Depth

Seasonal (2003-2009)

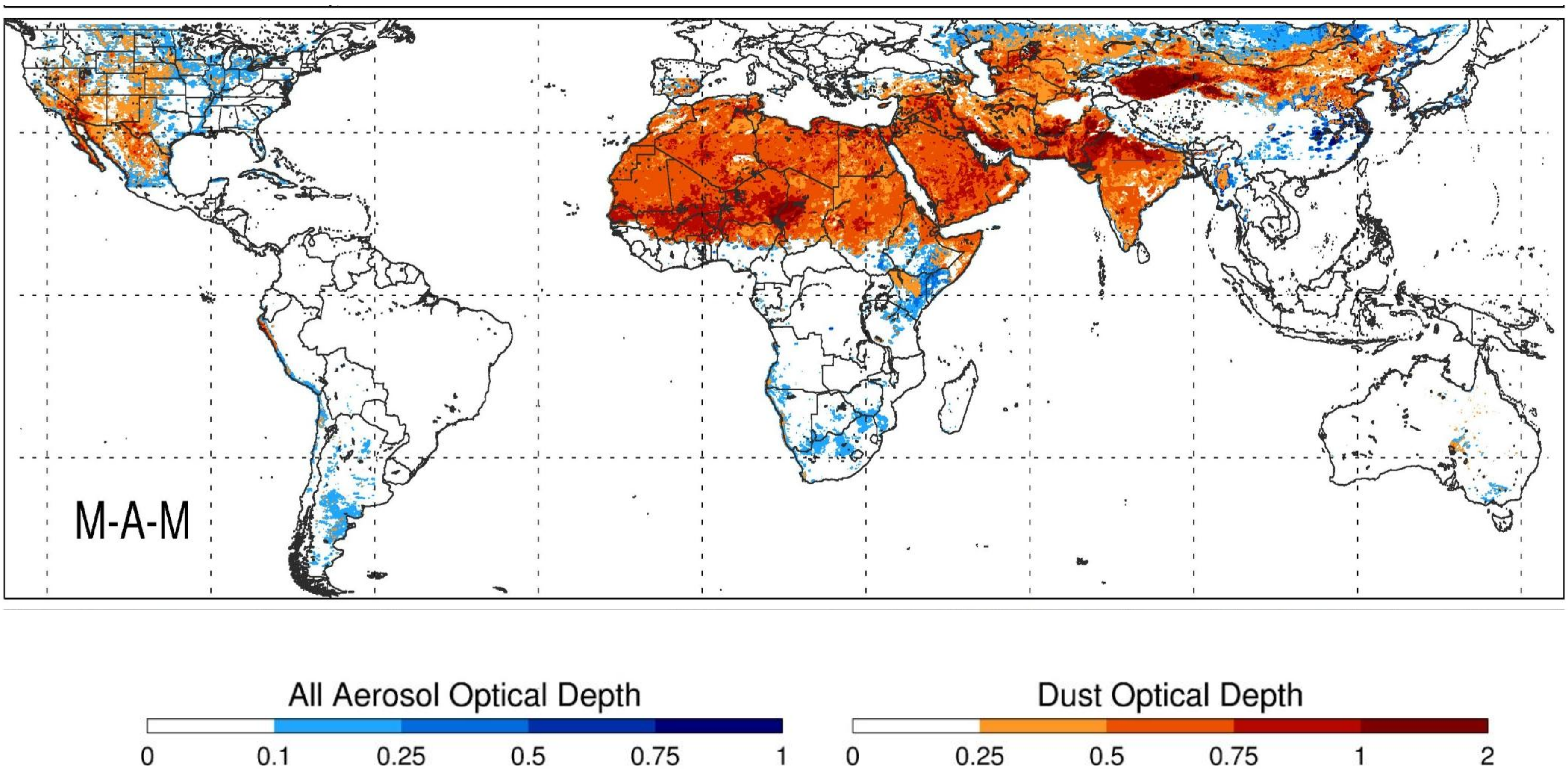


Method:

1. MODIS DB Level 2 collection 5.1 daily products are gridded on 0.1x0.1 degree grid from January 2003 to December 2009
2. DOD = scenes with $\alpha < 0$ and $\Delta\omega/\Delta\lambda > 0$
3. 7-year mean seasonal variation of AOD and DOD

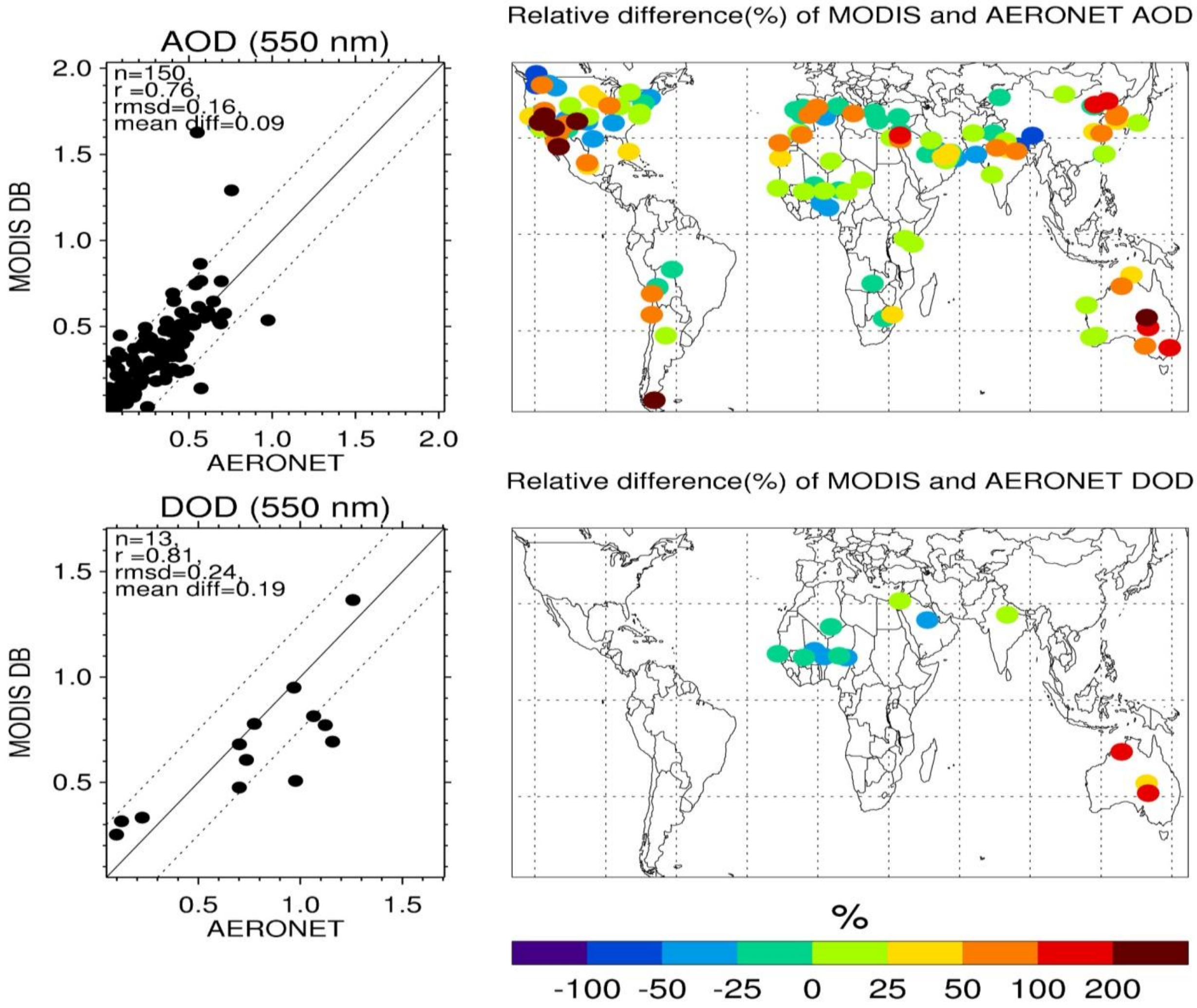
MODIS DB Dust Optical Depth

March-April-May (2003-2009)



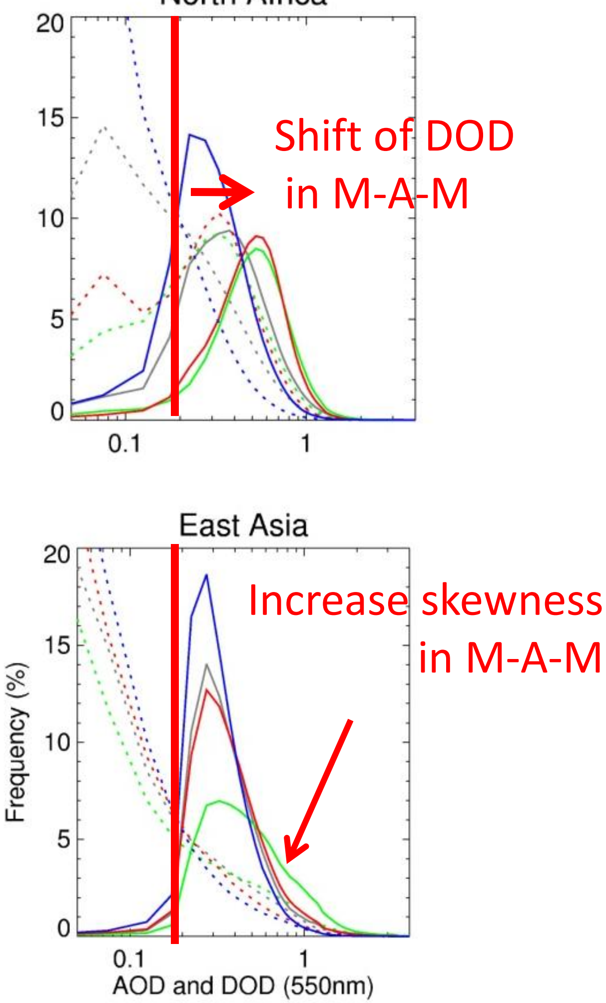
Comparison with AERONET data

Collocated sunphotometers



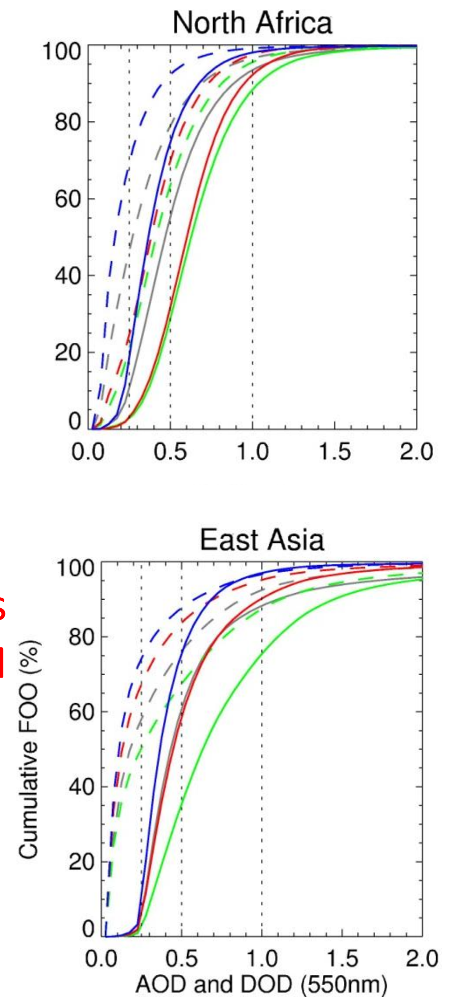
Frequency Distribution of seasonal DOD over North Africa and China

Frequency distribution



DOD is most frequently > 0.2

Cumulative frequency



Fitting frequency distribution
With lognormal (μ, σ)

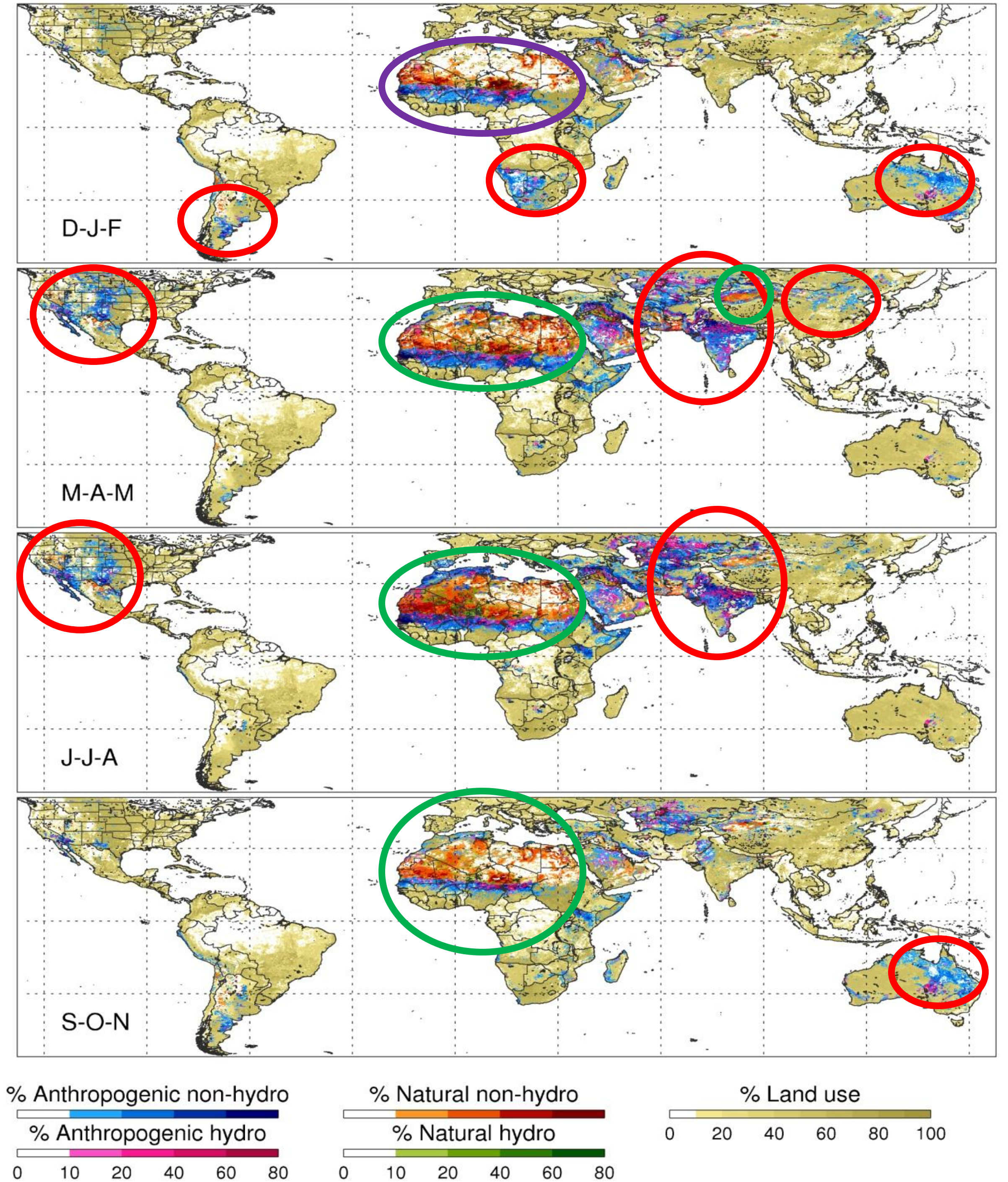
Region Name	M-A-M μ	σ
North Ame	0.466	1.62
South Ame	0.359	1.69
North Afric	0.565	1.54
South Afric	0.355	1.6
West Asia	0.57	1.61
Central Asi	0.59	1.65
East Asia	0.604	1.66
Australia	0.299	1.65

MODIS DB Dust Sources

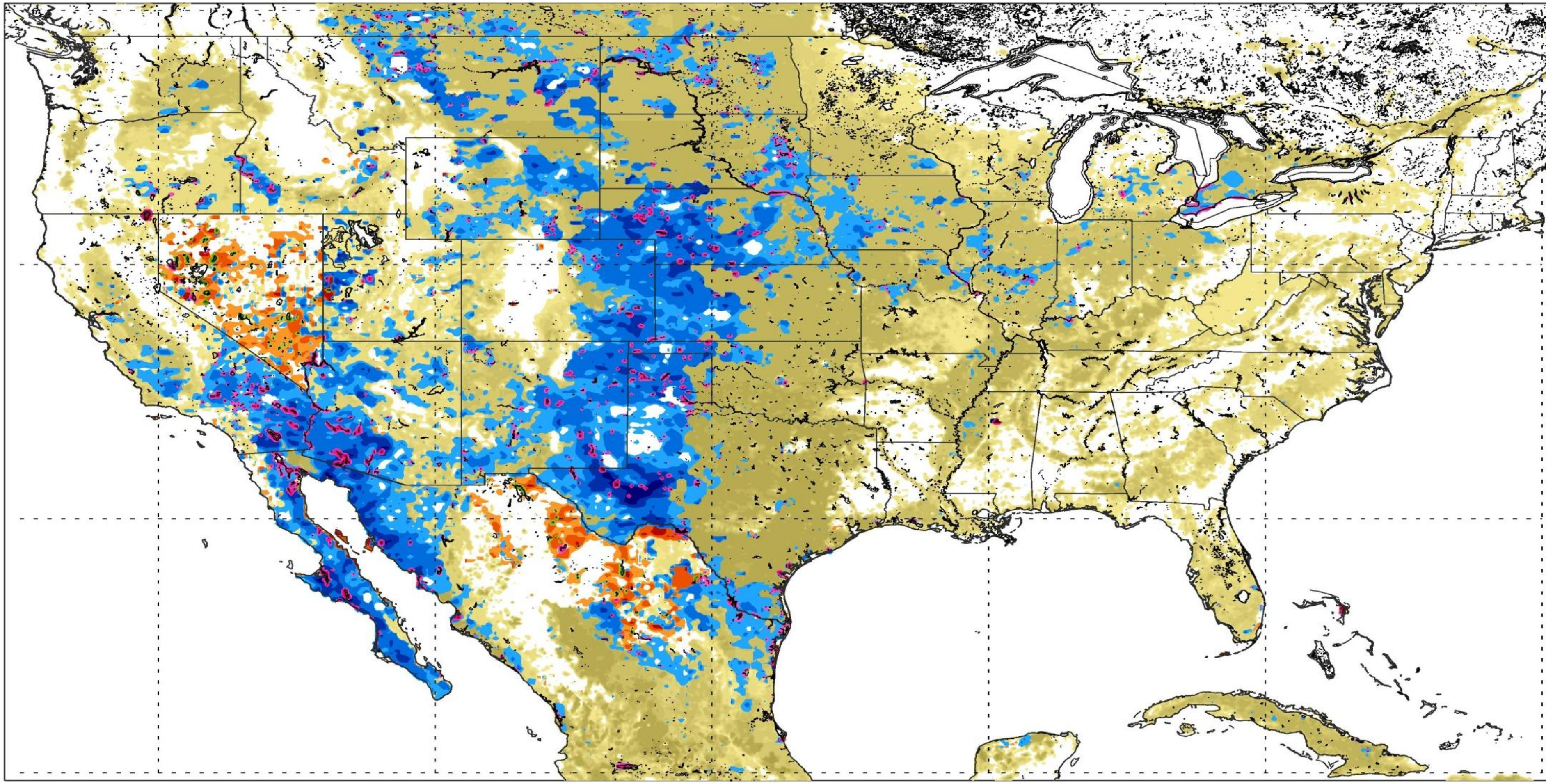
Dust sources identified by frequency of occurrence (FOO) of **DOD > 0.2**

Association of FOO with

1. **hydrographic features**:
   - ephemeral lakes, rivers, shallow lakes
   - dataset: 1x1km MODLAND
2. **Land use**:
   - agriculture (proxy for anthropogenic activities)
   - Dataset: 10x10km Klein Goldewijk, GBC, 2001

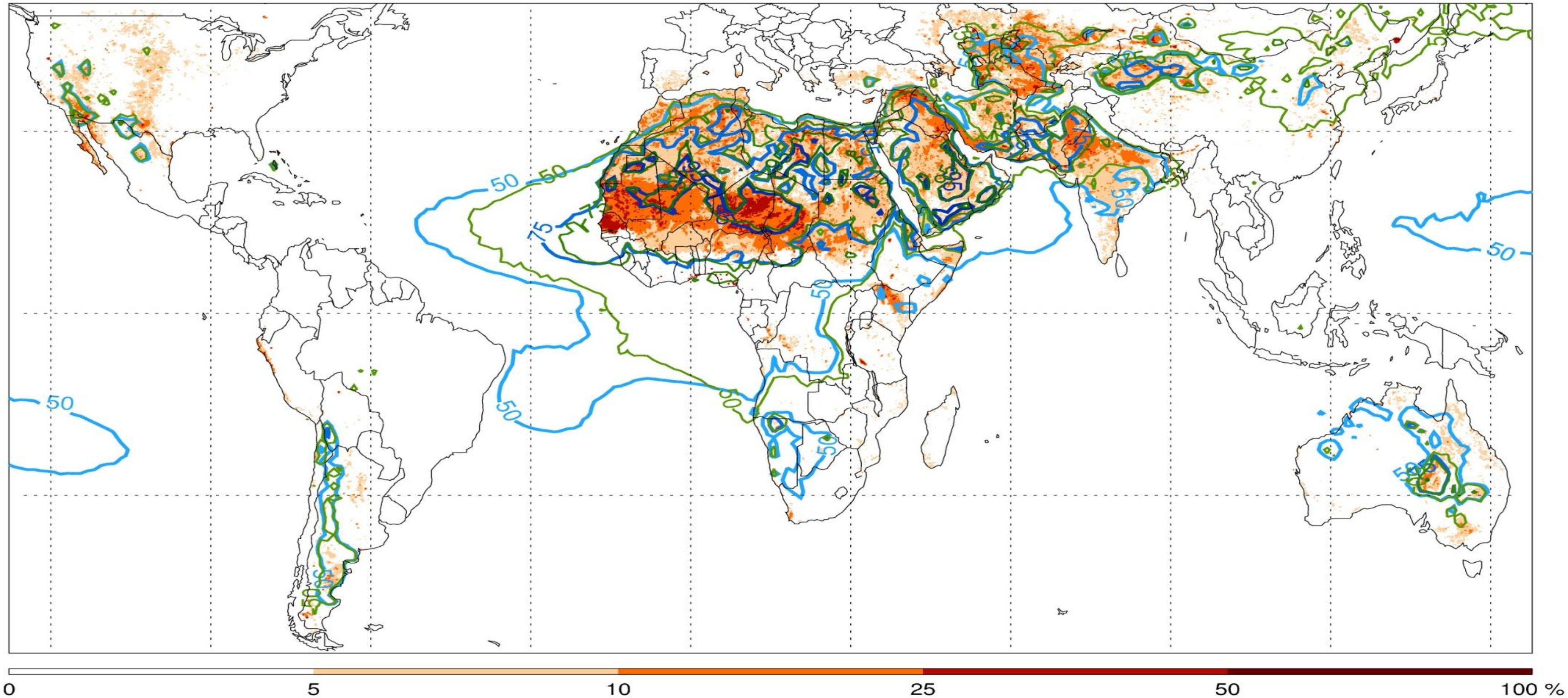

D-J-F
M-A-M
J-J-A
S-O-N
% Anthropogenic non-hydro
% Anthropogenic hydro
0 10 20 40 60 80
% Natural non-hydro
% Natural hydro
0 10 20 40 60 80
% Land use
0 20 40 60 80 100

US MODIS DB Dust Sources M-A-M



Mostly “anthropogenic” sources in Midwest and Southwest
Hydrographic origin in multiple locations
Mostly “natural” sources in Nevada, North Mexico

FOO of MODIS DB DOD>0.2, TOMS AI, and OMI AI>0.5



Overlapping of FOO TOMS and OMI AI, except East Asia
Overlapping MODIS DB and TOMS/OMI AI in most places, except US Midwest
MODIS DB outside Prospero et al. (RG, 2002) in India, Sahel, equatorial Africa

Dust emission

$$\text{Emission} = C\,L\,S\,w^2\,(w - w_t) \quad [\text{kg m}^{-2}\ \text{s}^{-1}]$$

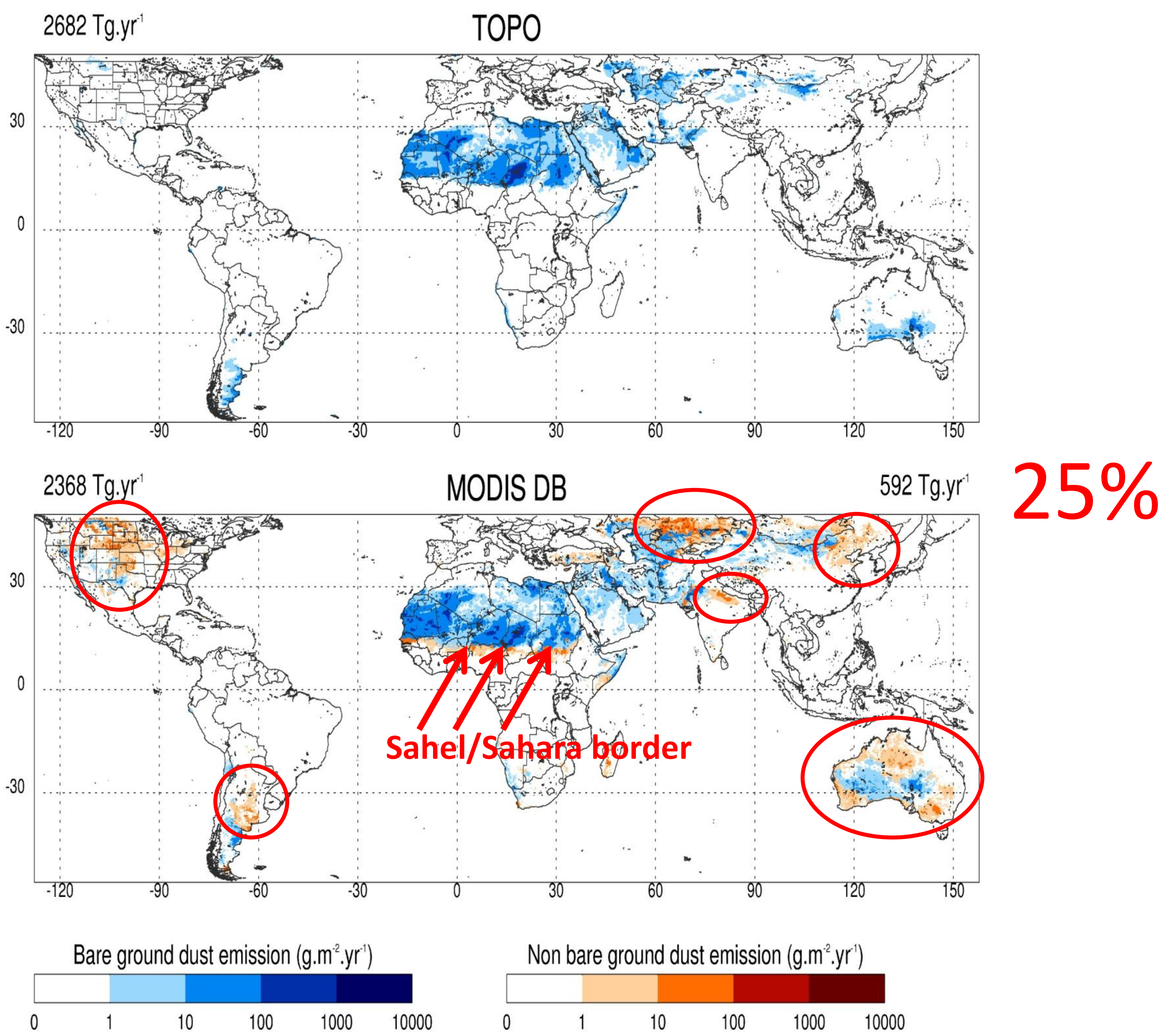
$C = 10^{-9}$ kg m^{-5} s^{2}

L =[0-1] land use fraction (Klein Goldewijk, GBC 2001)

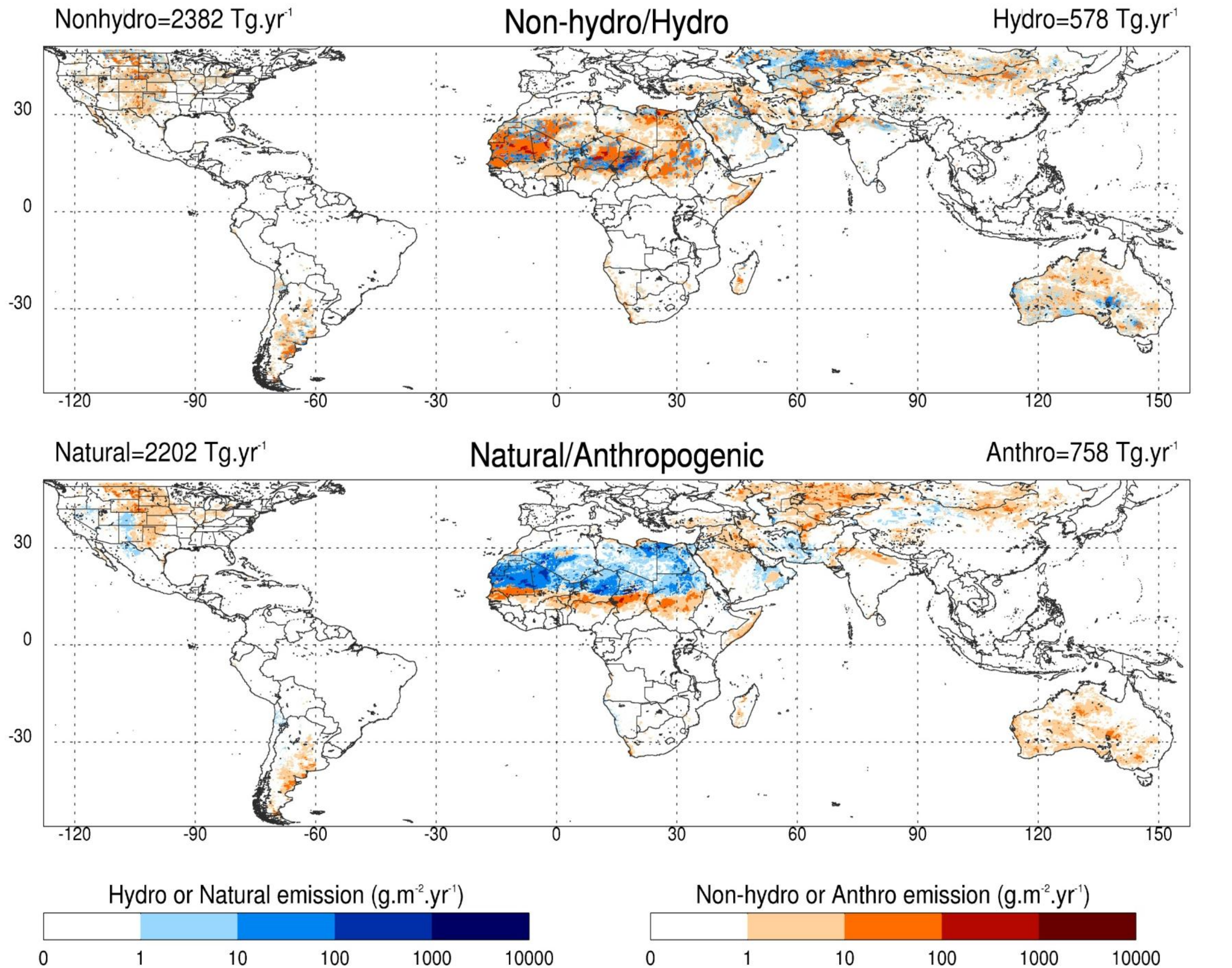
S=[0-1] from GOCART topographic depression
or MODIS DB FOO

w : 3-hourly 10-meter wind speed [m s^{-1}]
GFDL HIRAM cube-sphere (Zhao et al., JC 2009)
C360 (~25x25km)
2006

w_t=6 m s^{-1}



2682 Tg.yr-1
TOPO
2368 Tg.yr-1
MODIS DB
592 Tg.yr-1
25%
Sahel/Sahara border
Bare ground dust emission (g.m-2.yr-1)
Non bare ground dust emission (g.m-2.yr-1)
0 1 10 100 1000 10000


Nonhydro=2382 Tg.yr-1
Non-hydro/Hydro
Hydro=578 Tg.yr-1
Natural=2202 Tg.yr-1
Natural/Anthropogenic
Anthro=758 Tg.yr-1
Hydro or Natural emission (g.m-2.yr-1)
Non-hydro or Anthro emission (g.m-2.yr-1)
0 1 10 100 1000 10000

25%

30%

Conclusions

- New MODIS product:
  - DOD obtained by imposing $\alpha<0$ and $\Delta\omega/\Delta\lambda>0$
  - Satisfactory comparison with AERONET data
  - DOD is most frequently > 0.2
  - DOD frequency is lognormal distributed with seasonal shifts of mean and skewness
- MODIS DB dust sources
  - obtained from FOO distribution
  - Emission calculated using HIRAM C360
  - 25% additional to topographic depression (GOCART)
  - 25% associated with hydrographic features
  - 30% associated with land use (upper limit for “anthropogenic”)

Acknowledgements

Christina Hsu (NASA GSFC) : MODIS DB products

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PI of AERONET sunphotometers: AOD

Ming Zhao (NOAA GFDL): HIRAM C360 surface winds