Natural and Anthropogenic dust hot spots and their variability derived from satellite based products

By

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Questions we want to address concerning dust and its sources:

1. Where are located the hot spots?
2. Do they have a geomorphologic signature?
3. Is there an anthropogenic signature?

To answer these questions:

1. **Detection** of the location and frequency of dust events globally
2. **Attribution** of geomorphologic and land use origin
3. **Contribution** from each source types to dust emission

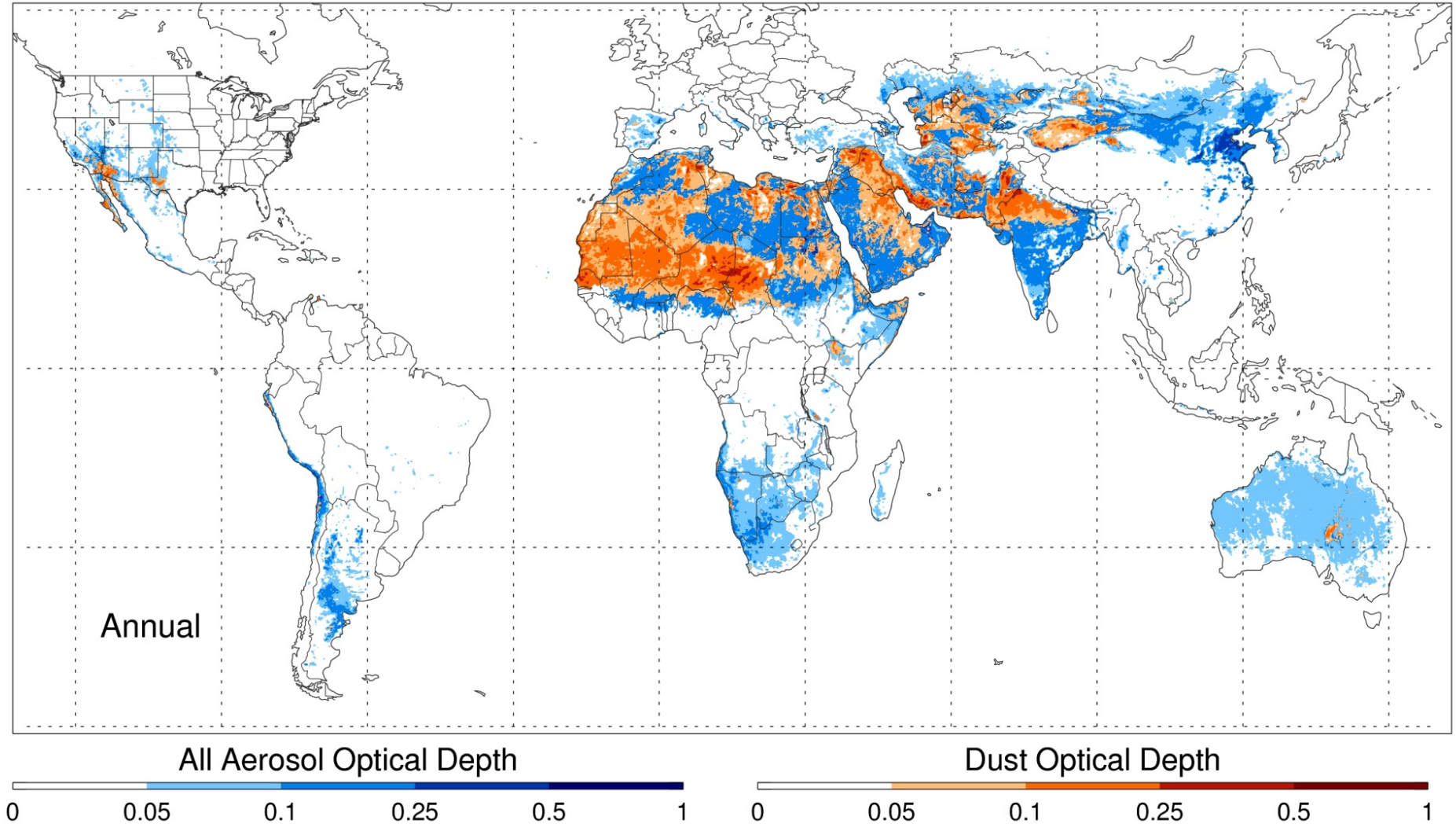
Detection

Three criteria applied to MODIS Aqua Deep Blue Level 2 aerosol products to extract Dust Optical Depth (DOD)

1. Low Angstrom exponent: Coarse mode particles
2. Increasing single scattering albedo with wavelength: Dust is more absorbing inthe blue than red

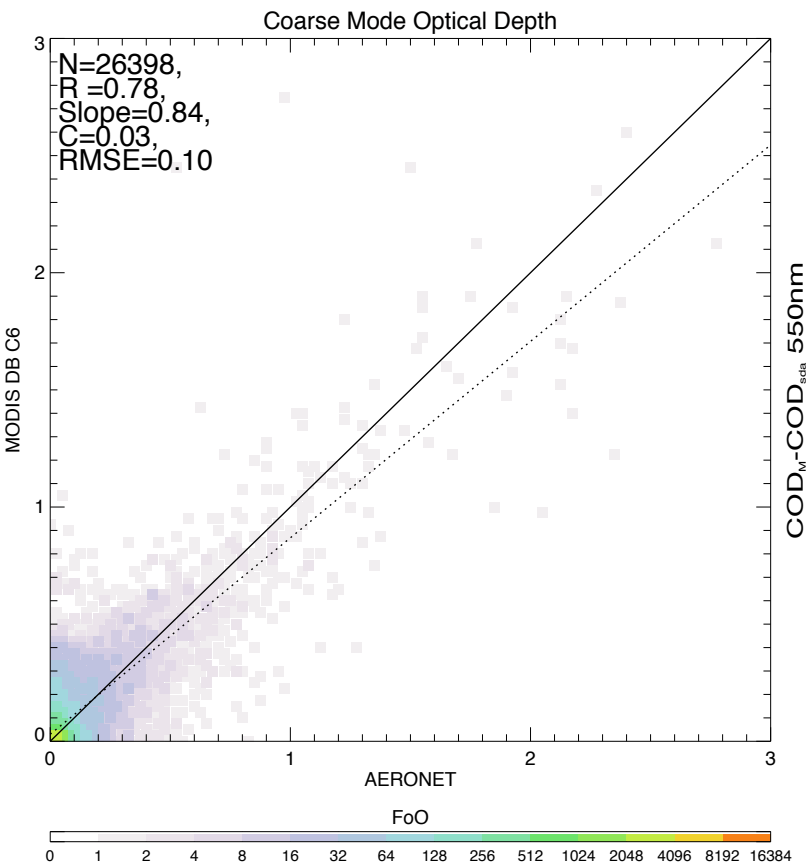
Global daily dust optical depth (DOD) at 0.1^0x0.1^0 from 2000 for MODIS on Terra, and 2003 for MODIS on Aqua

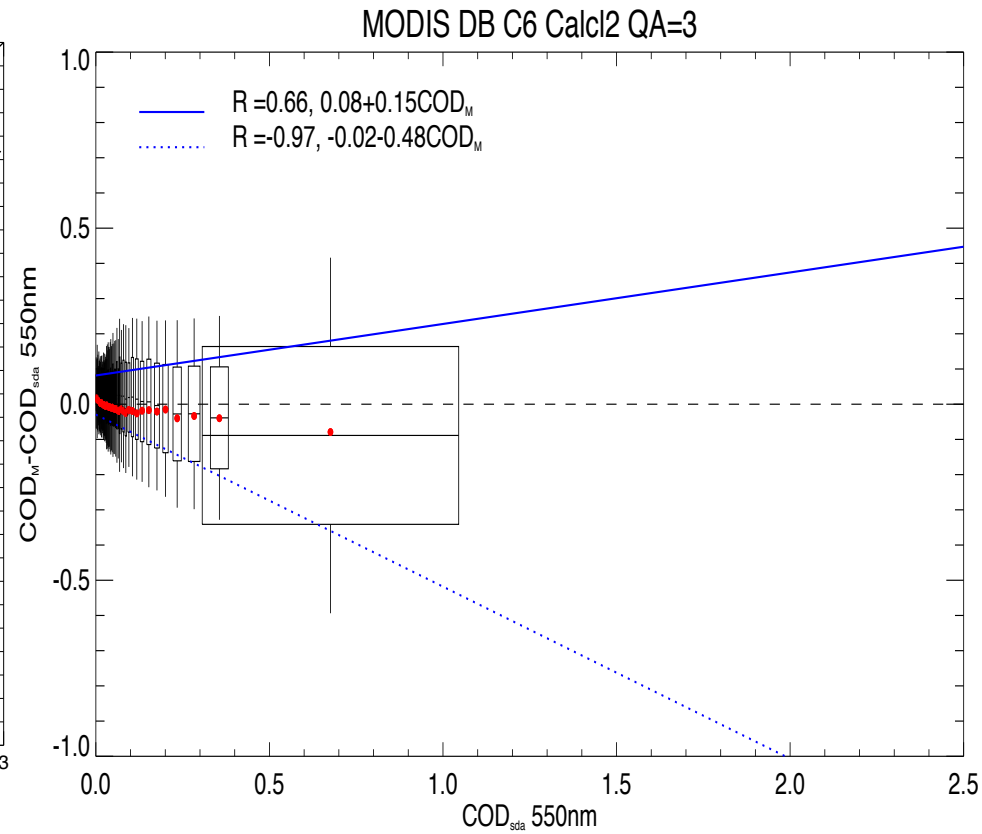
Global annual mean M-DB2 AOD & DOD



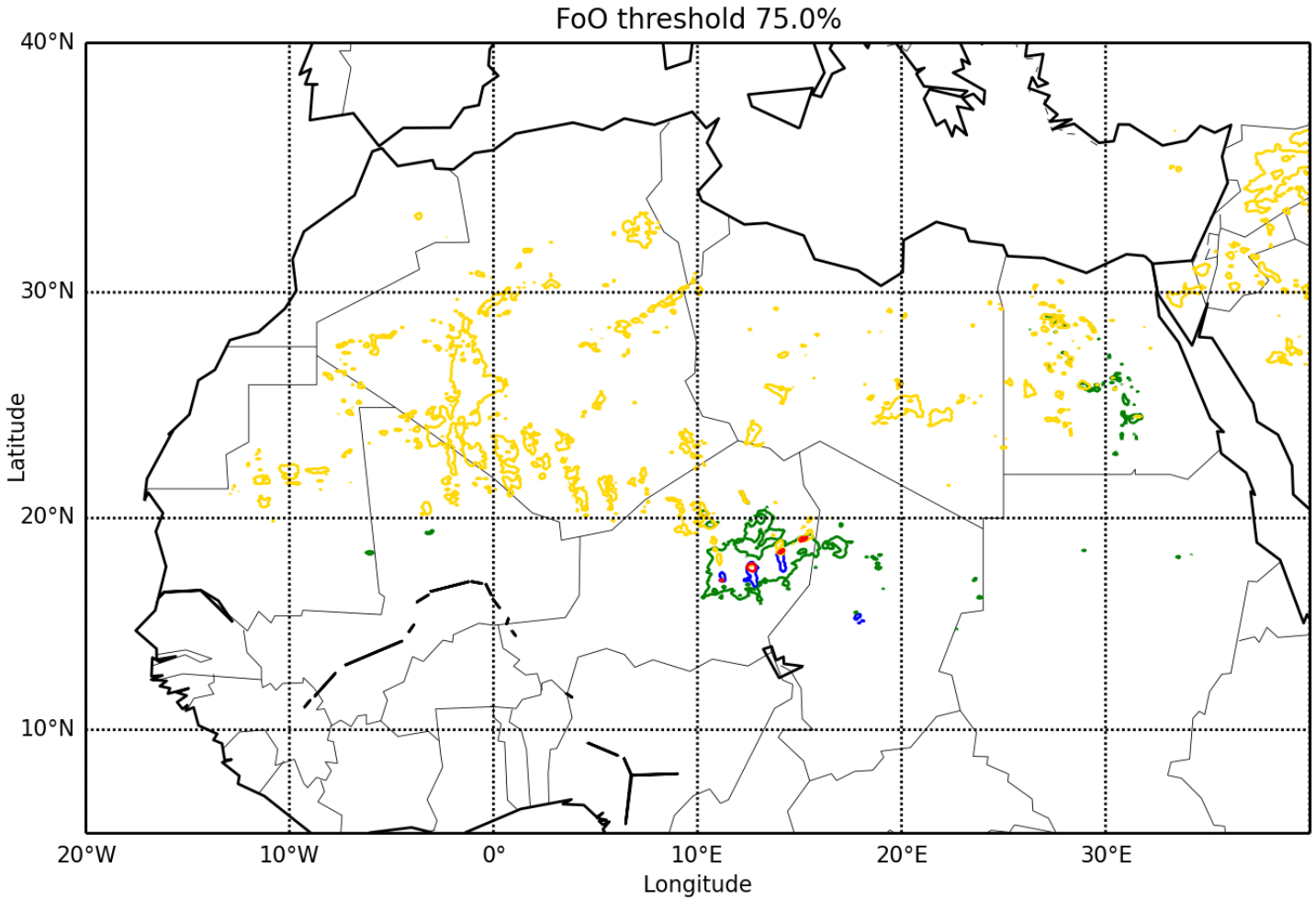
Comparison with AERONET

Comparison M-DB2 C6 Dust Optical Depth (DOD) with collocated (+/−10 km, +/- 30 min) AERONET SDA L2 *(O'Neill et al., J. Geophys. Res., 2003)* Coarse Mode optical depth (COD)



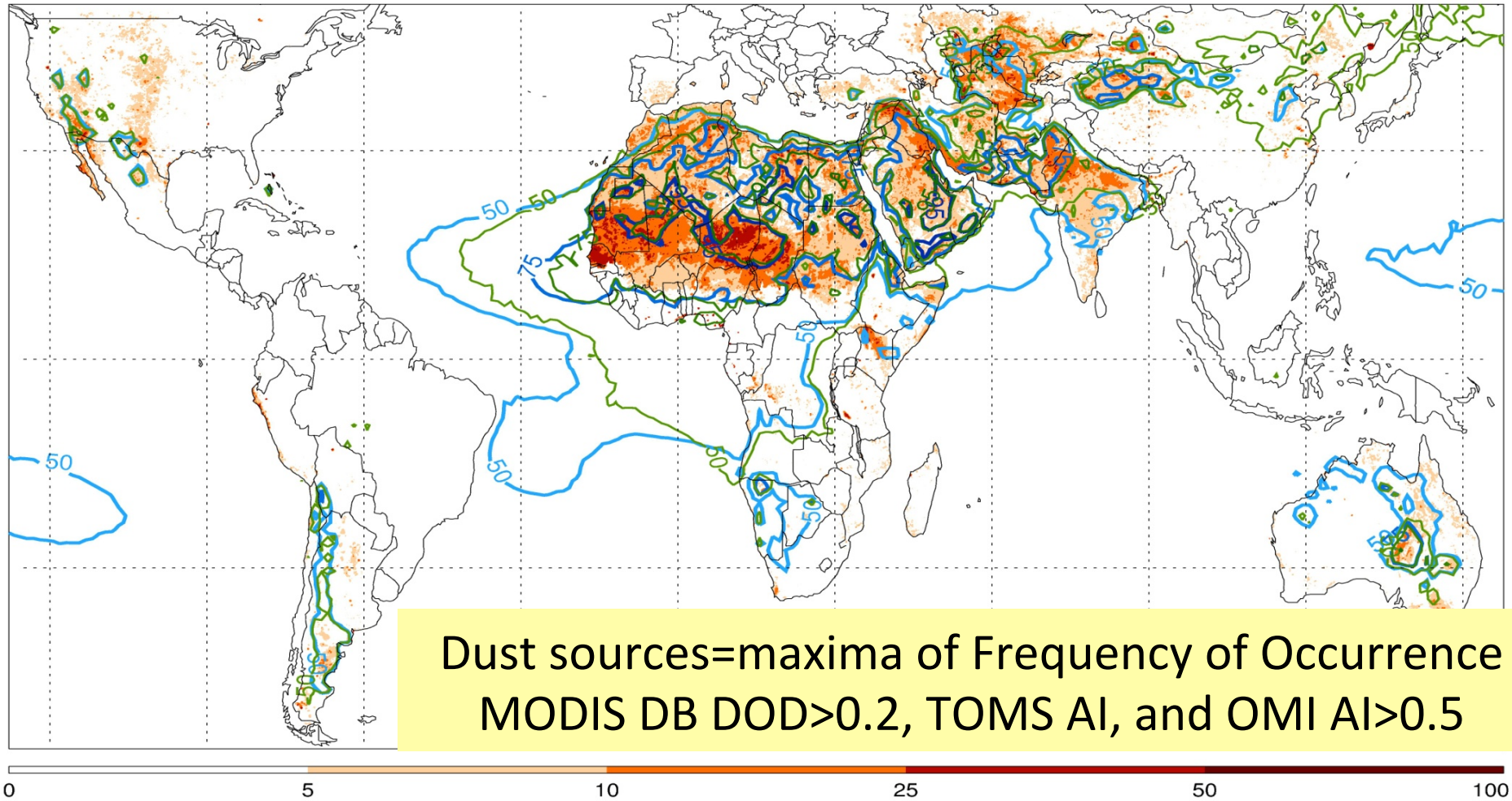


Frequency of Occurrence (FoO) of DOD>0.2



DJF **MAM** **JJA** **SON**

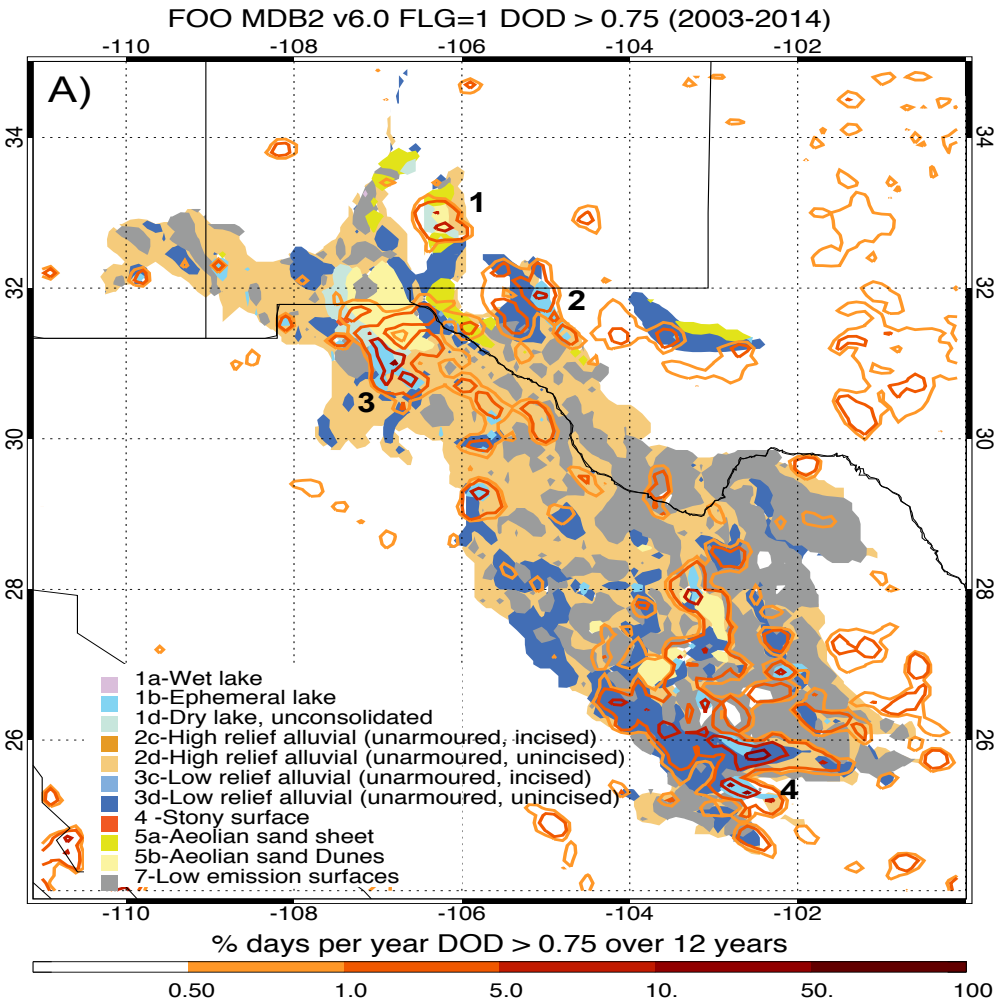
Dust Sources

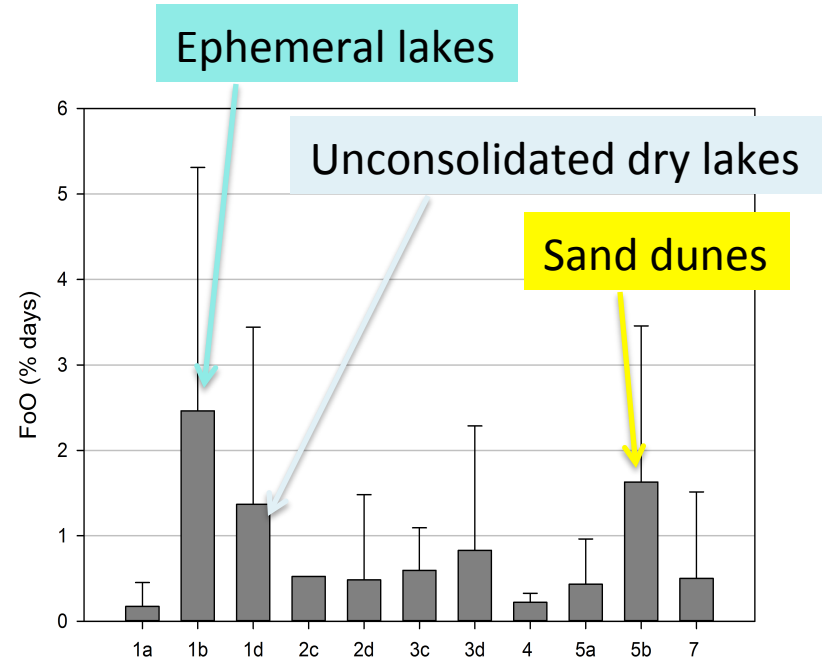


Dust sources=maxima of Frequency of Occurrence
MODIS DB DOD>0.2, TOMS AI, and OMI AI>0.5

Overlapping of FoO TOMS (Blue) and OMI AI (Green), except East Asia
Overlapping M-DB2 (red shading) and TOMS/OMI AI in most places, except US High Plains.

Geomorphology of most active sources: Case of Chihuahuan desert





Most active and intense natural dust sources are associated with 3 geomorphological surfaces:

1. ephemeral lakes,
2. sand-dunes,
3. unconsolidated dry lakes.

Baddock et al., Geophys. Res. Lett., 2015

Attribution

Dust sources are attributed a natural, anthropogenic or hydrologic origin based on the fraction of

1. **Land use**:
   - agriculture +pasture for 2000
   - Dataset: HYDE3 10x10km Klein Goldewijk, GBC, 2001

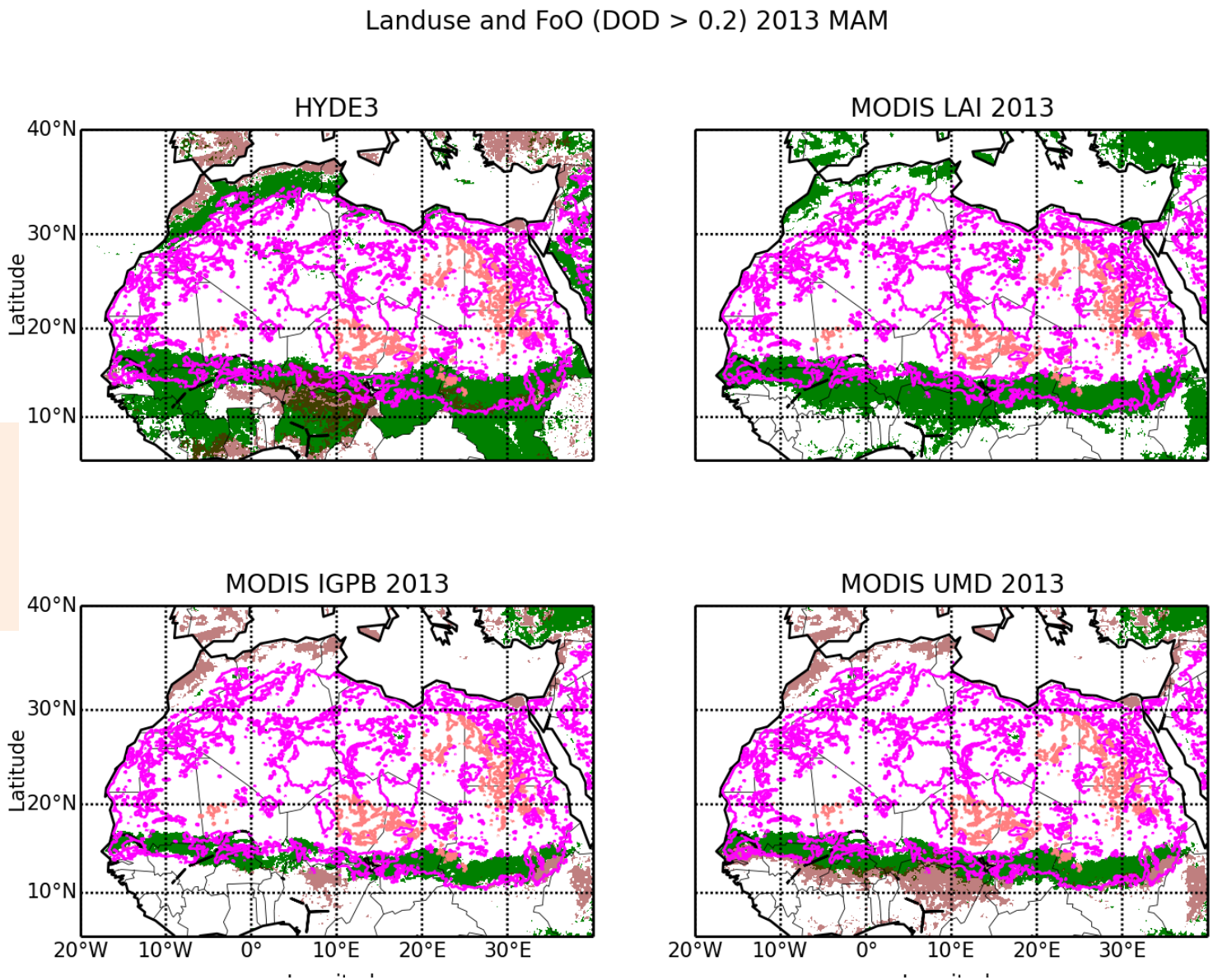
   Anthropogenic **if land use > 30%**

   Natural **if land use < 30%**

2. **Ephemeral water bodies**:
   - ephemeral lakes, rivers, shallow lakes
   - dataset: 1x1km MODLAND

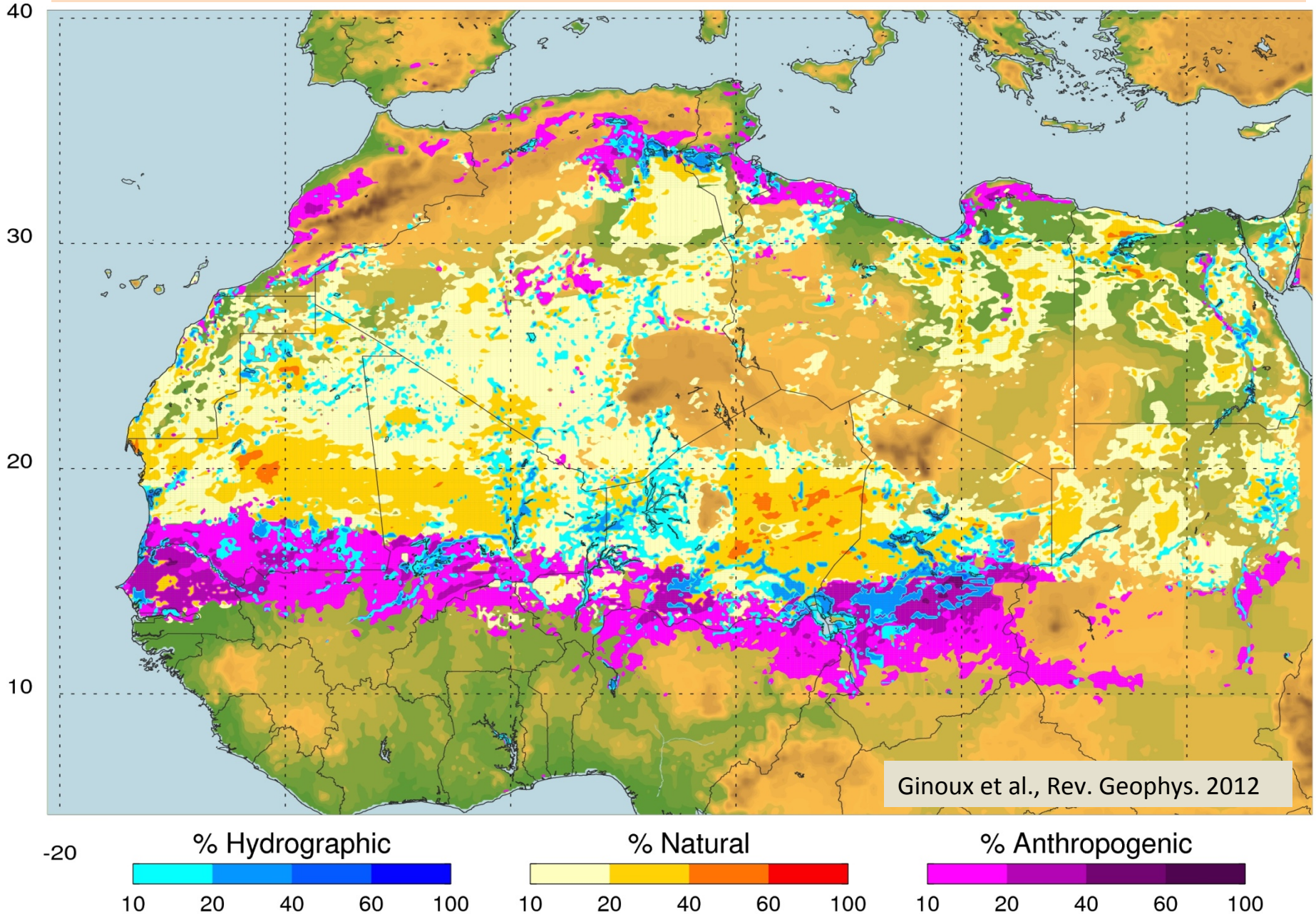
   Hydrologic **if water body > 10%**

FoO and Land Use Datasets



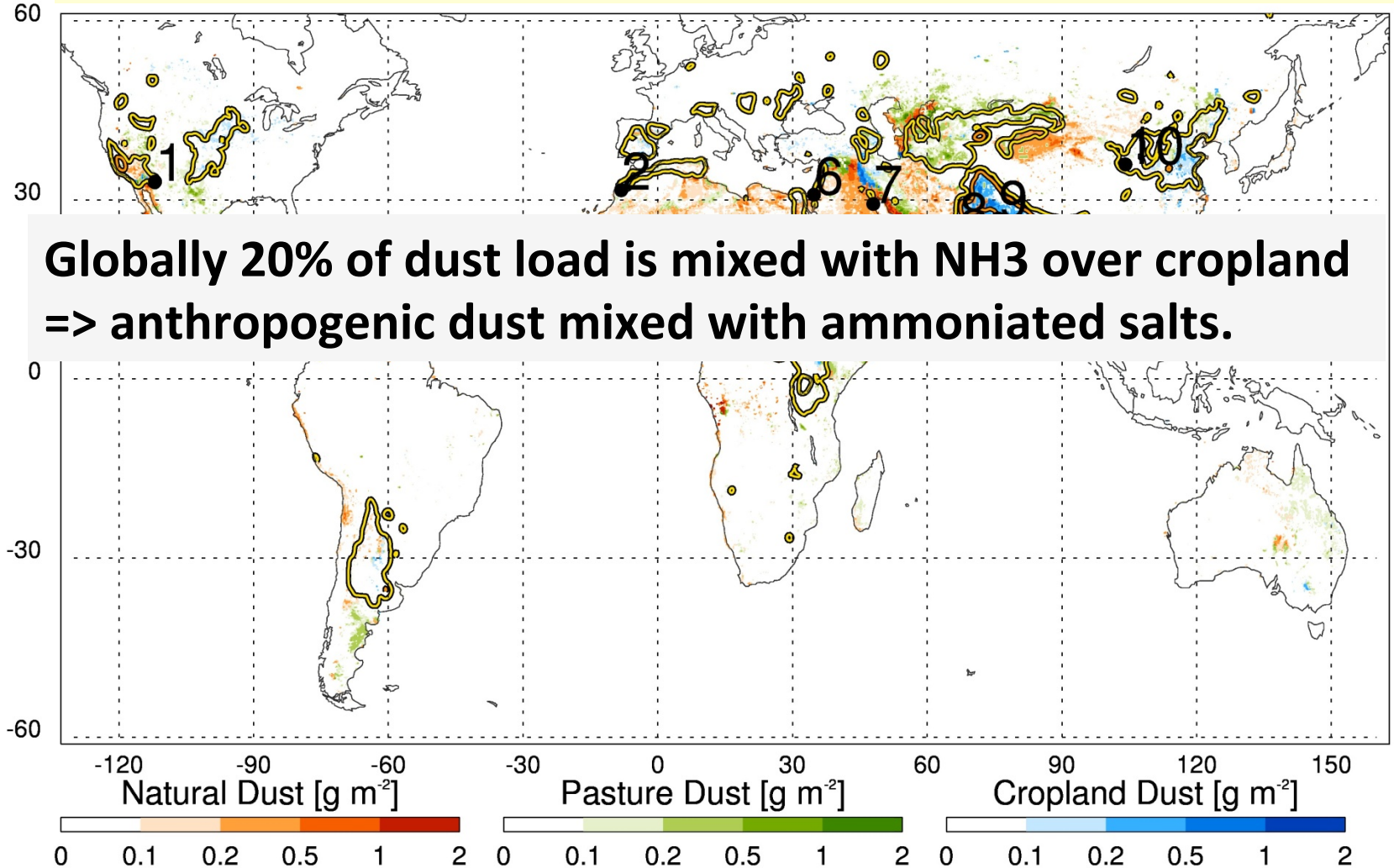
Green: Pasture
Tan: Cropland
Magenta: 5% FoO
Orange: 25% FoO

Annual mean FoO M-DB2 DOD> 0.2



Observed mixing of dust and NH3 over cropland

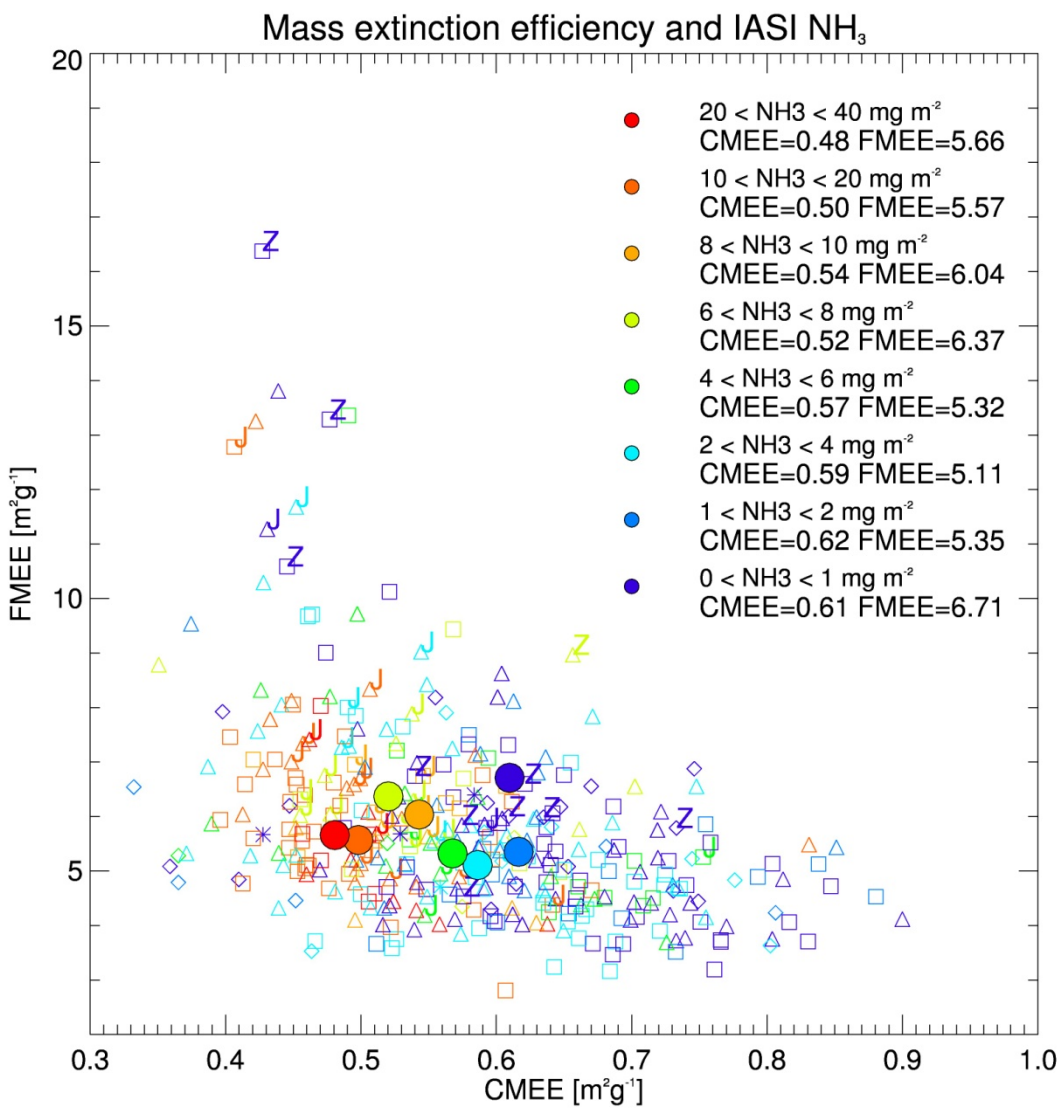
Annual mean MODIS DB dust and IASI NH3 (Clarisse et al., Nature 2009)



Globally 20% of dust load is mixed with NH3 over cropland => anthropogenic dust mixed with ammoniated salts.

Ginoux et al., ACP, 2012

Dependency of mass extinction efficiency on NH_3



Ginoux et al., Atm. Chem. Phys., 2012

Collocated IASI NH_3 retrievals and AERONET sunphotometers inversion data (Dubovik et al., 2002) in Sahel (Zinder) and India (Jodhpur)

Coarse Mode Extinction Efficiency (CMEE) decreases up to 50% with increasing NH_3.

Emissions

Dust flux = $C\ S\ v^2\ (v - v_t)$ [kg m^{-2} s^{-1}] (Ginoux et al., 2001)

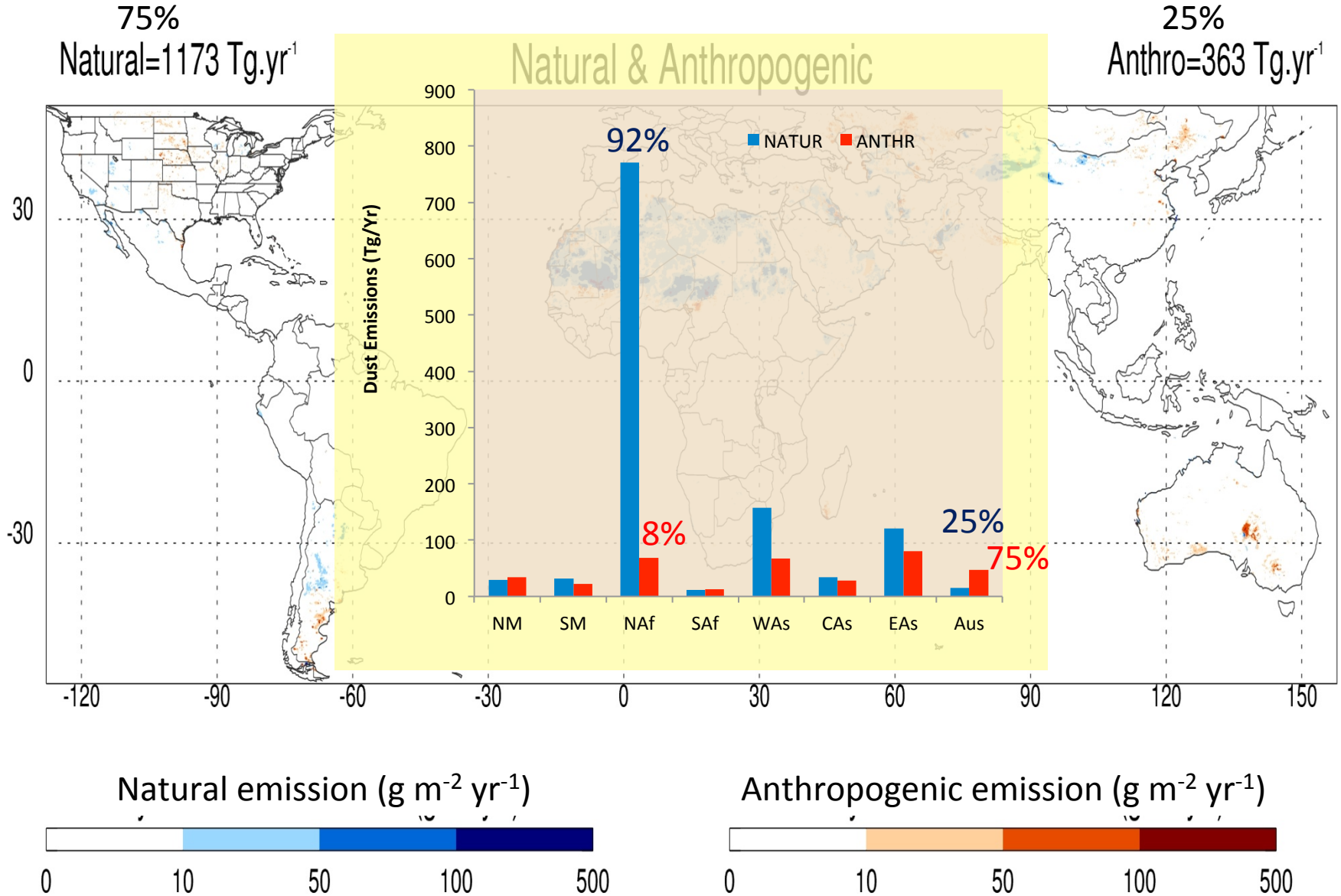
$C = 2\ 10^{-9}$ kg m^{-5} s^2

S=[0-1] MODIS DB FoO with seasonal variation

v : 10-meter wind speed (GFDL HIRAM ~25km)

v_t= 6-10 m s^{-1} threshold of wind erosion

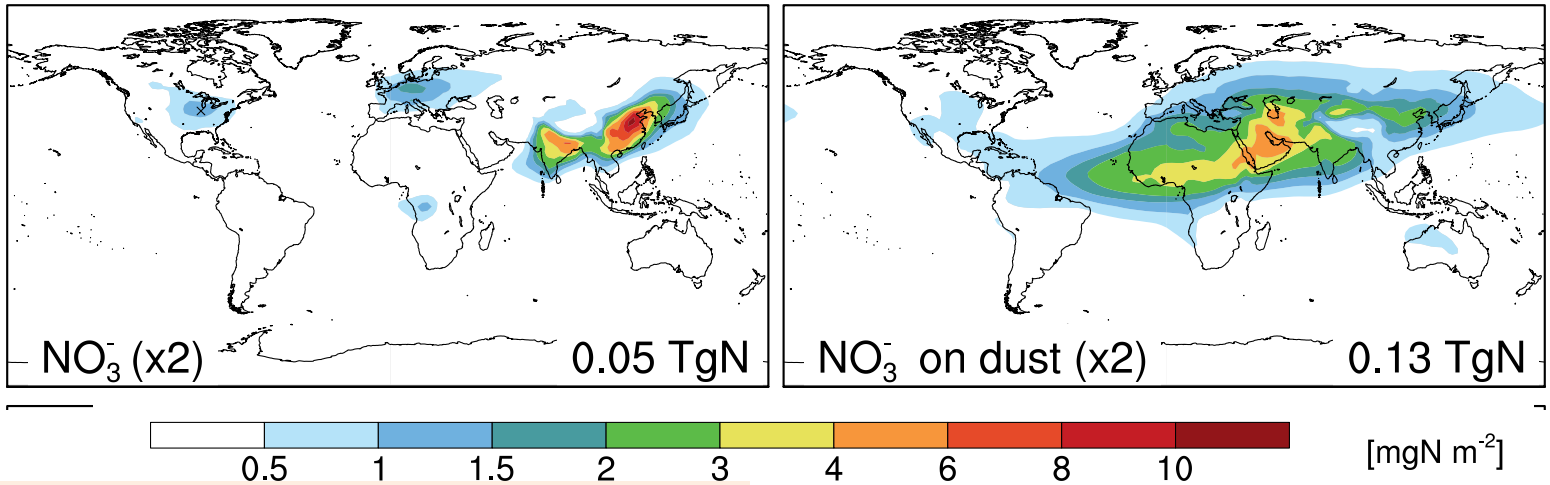
Natural & Anthropogenic annual emissions



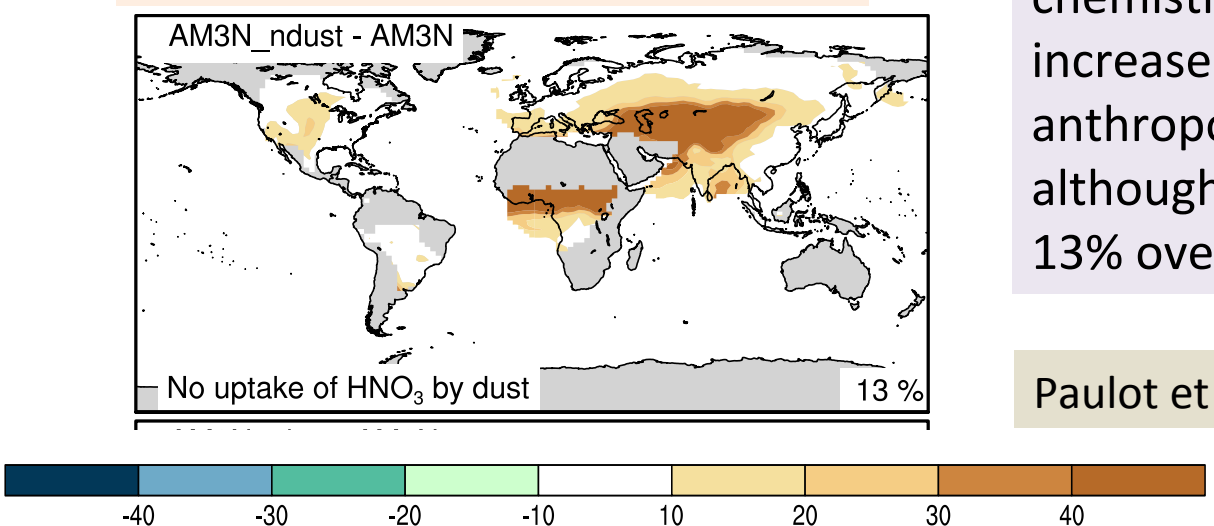
Ginoux et al., Rev. Geophys., 2012

Anthropogenic dust and nitrate

Burden of fine mode nitrate and nitrate on dust using GFDL CM3 model



% change of nitrate optical depth by neglecting HNO3 uptake on dust



Neglecting heterogeneous chemistry on dust results in 30% increased nitrate optical depth in anthropogenic dusty regions, although globally it represents only 13% overestimation.

Paulot et al., Atm. Chem. Phys., 2015

Conclusions

- MODIS Deep Blue aerosol products are well suited to study dust events: Resolution, global coverage, spectral data with strong variation of dust absorption (blue/red).

- FoO of MODIS DOD allows to detect hot spots. These hot spots are often associated with ephemeral lakes with nearby sand sheets.

- Collocation of MODIS DOD and IASI NH_3 plumes indicates global extend of dust from agriculture, which affects dust properties with a reduction of mass extinction efficiency as NH_3 burden increases.

- . Anthropogenic sources account for 25% global emissions, with large regional differences: lowest (highest) contribution in North Africa (Australia). However, there is large uncertainties with the selection of the land use dataset.

- Including HNO_3 uptake on dust decreases nitrate optical depth by ~13% globally, and regionally by 30% when associated with land use dust.