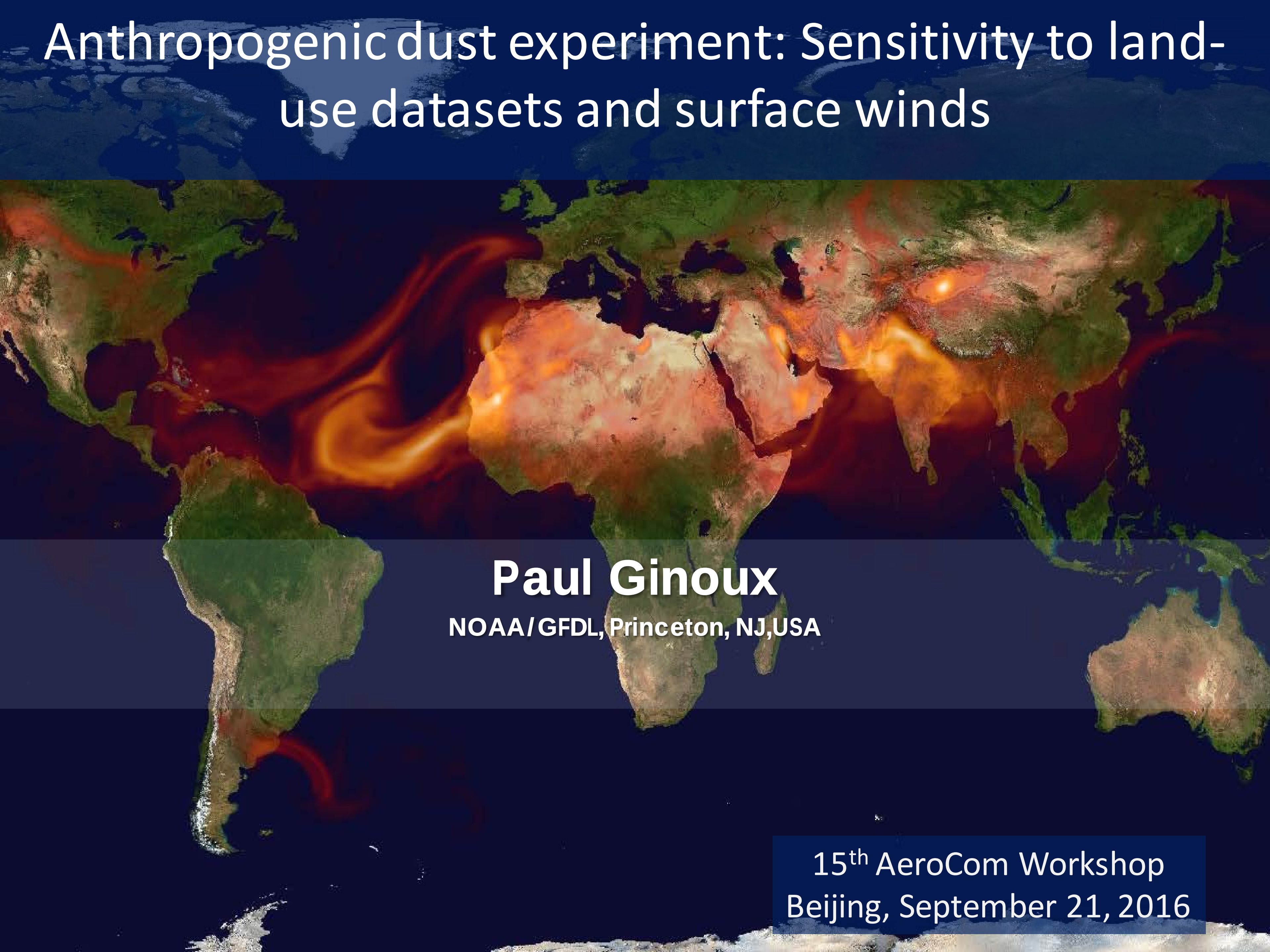
Anthropogenic dust experiment: Sensitivity to land-use datasets and surface winds



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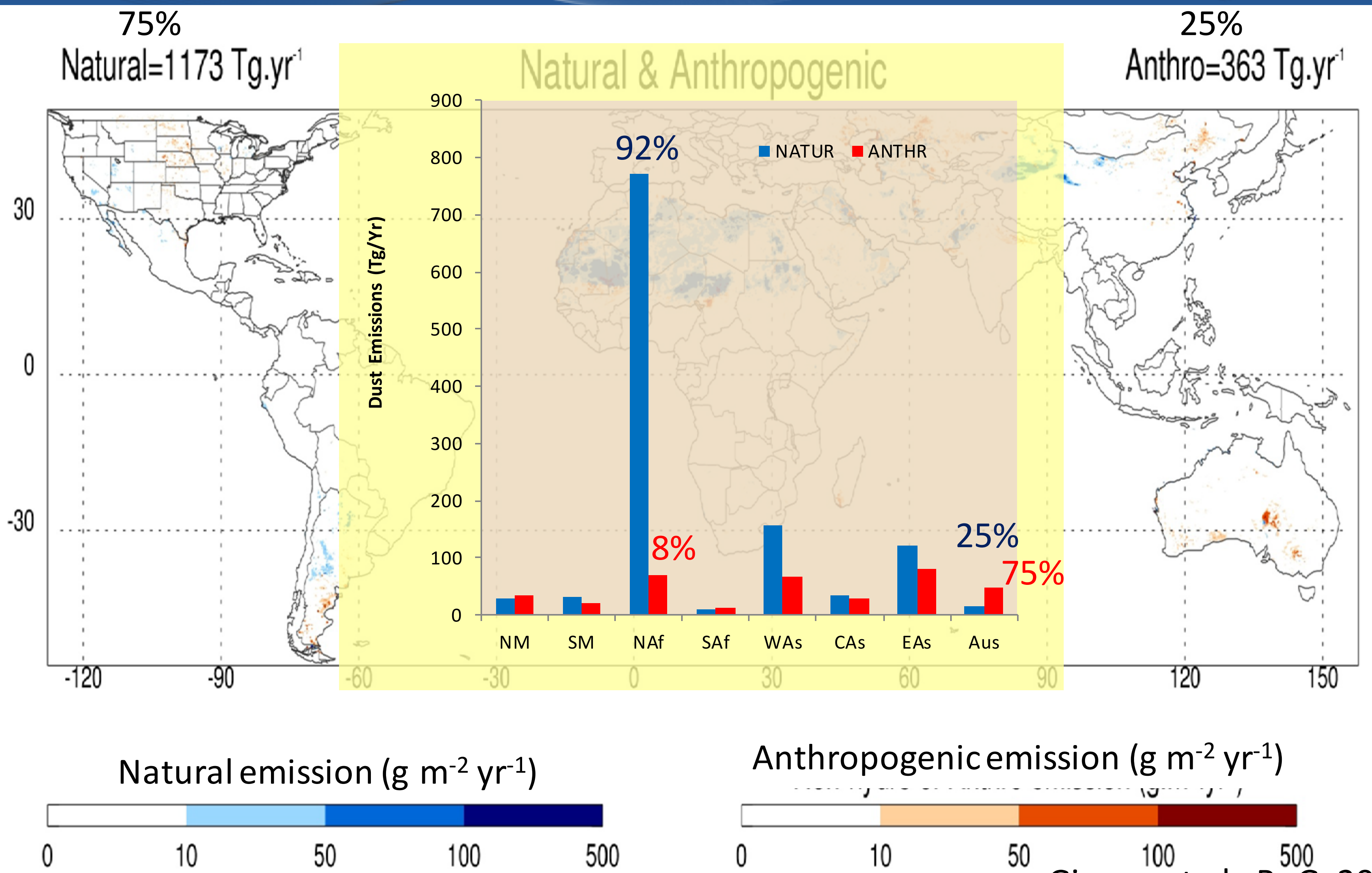
15th AeroCom Workshop
Beijing, September 21, 2016

AnthroDust: Motivations

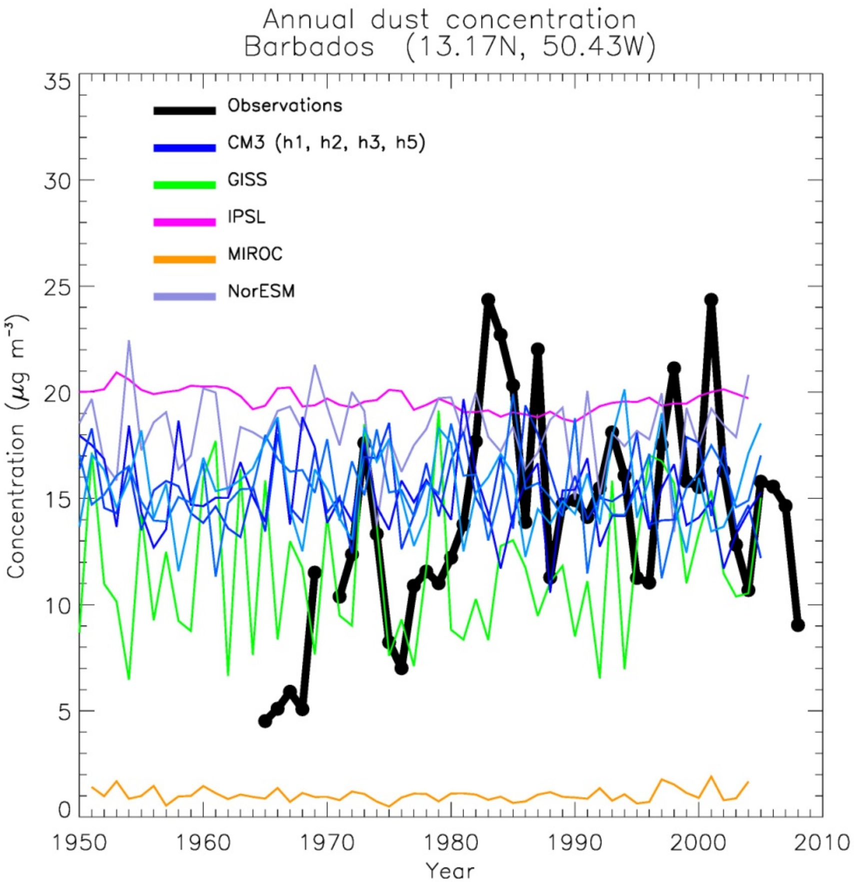
- Model based estimates of dust contribution from landuse to **global emission** vary between 0 to 60% (Mahowald et al., 2003). New estimates are around 10 to 25%(*Ginoux et al., Rev.. Geophys., 2012; Stanelle et al., J. Geophys. Res., 2014*) with large continental variability.
- Mineralogy of natural and landuse dust differs, which has implication for radiative forcing, ocean biogeochemistry, heterogeneous reactions with gas phase chemistry,
- Landuse dust and NH_3 hotspots are often collocated (*Ginoux et al., Atm. Chem. Phys., 2012*) which has implication for nitrate production (*Paulot et al., Atm. Chem. Phys., 2015*).

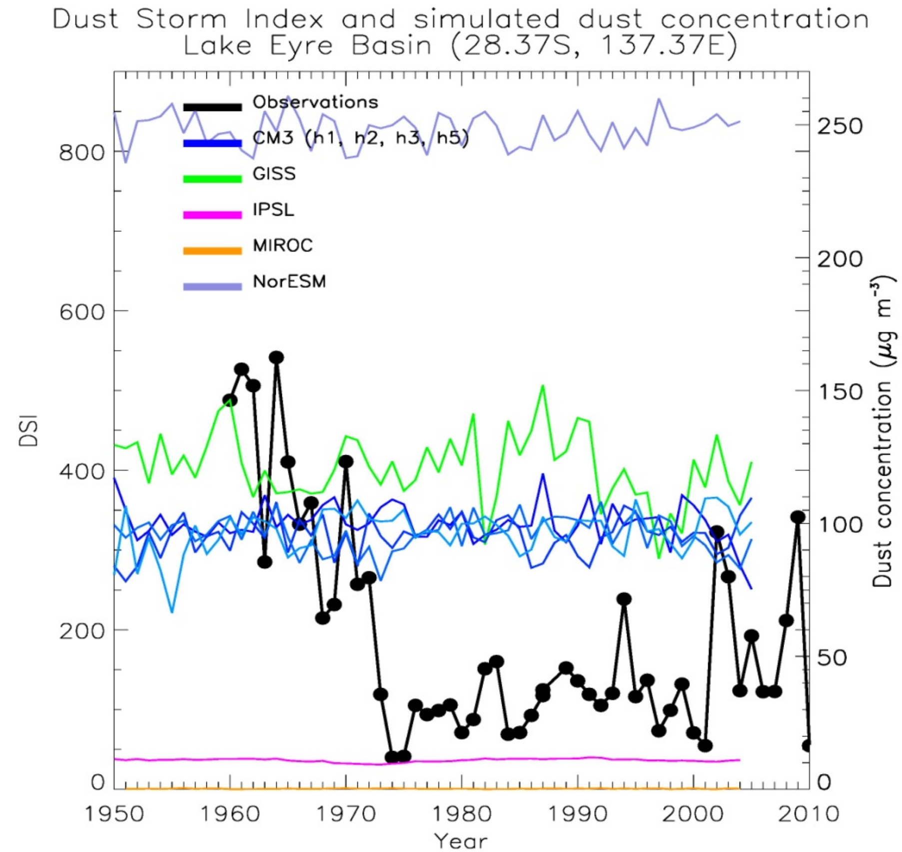
MODIS based contribution of anthropogenic dust



Ginoux et al., RoG, 2012

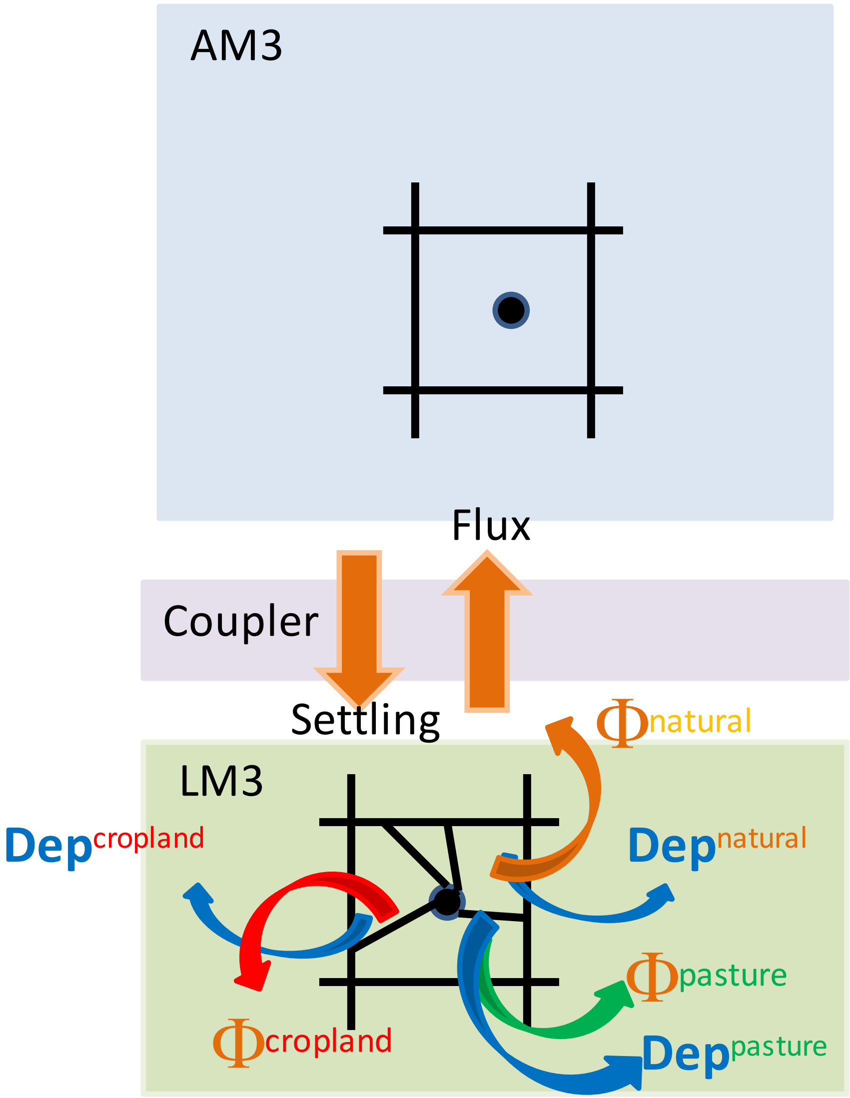
Simulation of dust decadal variation with GCMs





There is a large spread of results between CMIP5 surface dust concentrations, but they lack of decadal variability. Is this related partially to landuse?

Dust emission in GFDL Dynamic Land MOdelLM3



- Dust emission and deposition are calculated within each sub-grid tiles (natural, secondary vegetation, pasture and cropland) of LM3,
- Dust emission is parameterized as a function of surface friction velocity and threshold speed of wind erosion (soil moisture, leaf area)
- Settling and convective fluxes are exchanged between the atmosphere and the canopy,

Ginoux P., Malyshev S., and E. Shevliakova, manuscript in preparation.

GFDL CM3 with Landuse Dust

GFDL Coupled Models CM3: 2°x2.5°, 48 levels

Simulation: 1950 to 2010

Aerosols: GOCART-like with simplified chemistry for sulfate

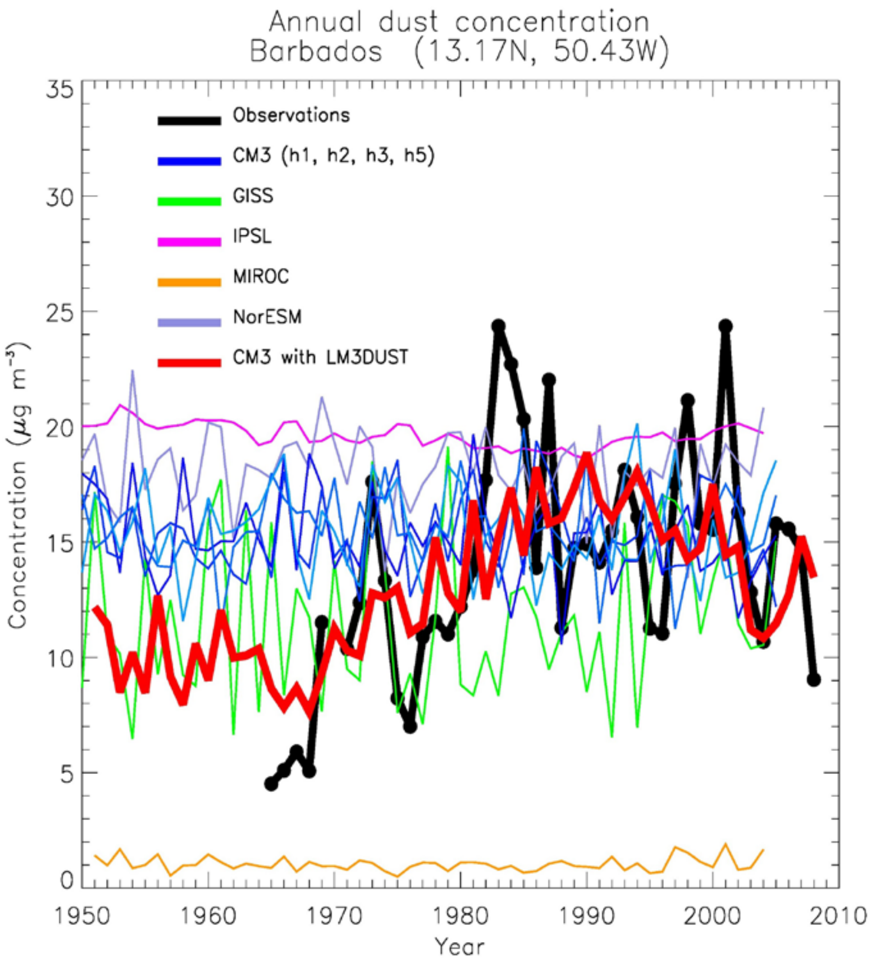
Nudging: U, V with NCEP re-analysis

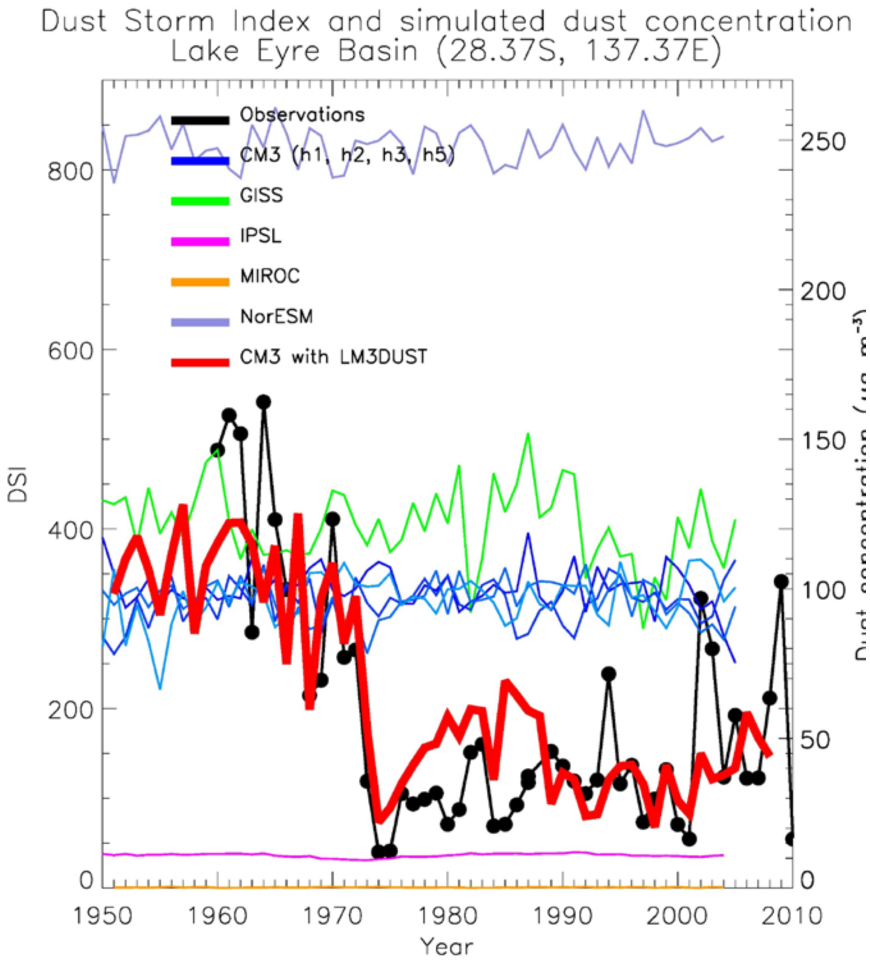
Initial Condition: IPCC AR5 CM3 for 1950

Boundary Conditions: exact same forcings as IPCC AR5

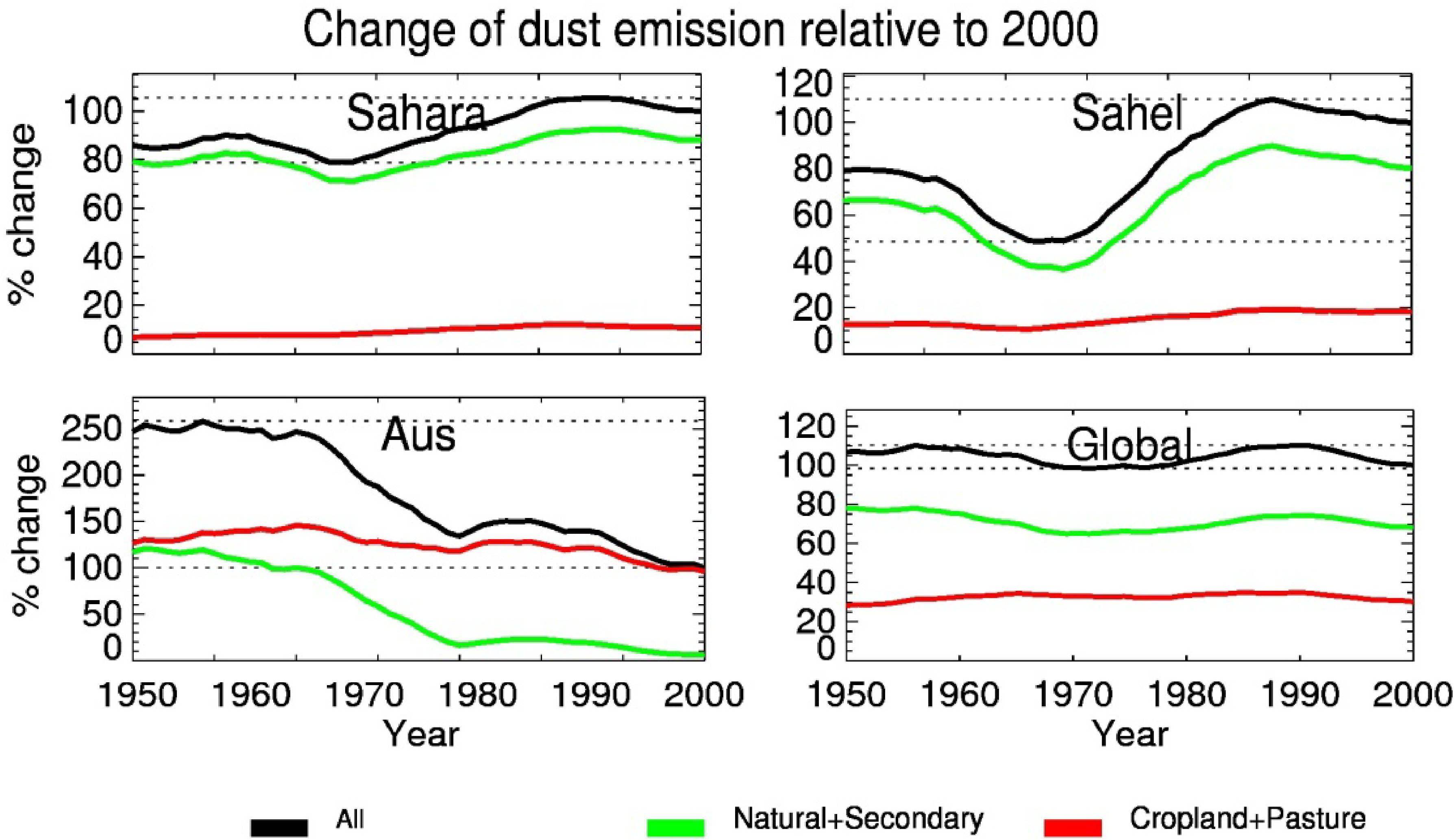
Ocean: sea surface temperature override with HadSST.

Simulated dust decadal variation with LM3





Natural/Landuse dust emission



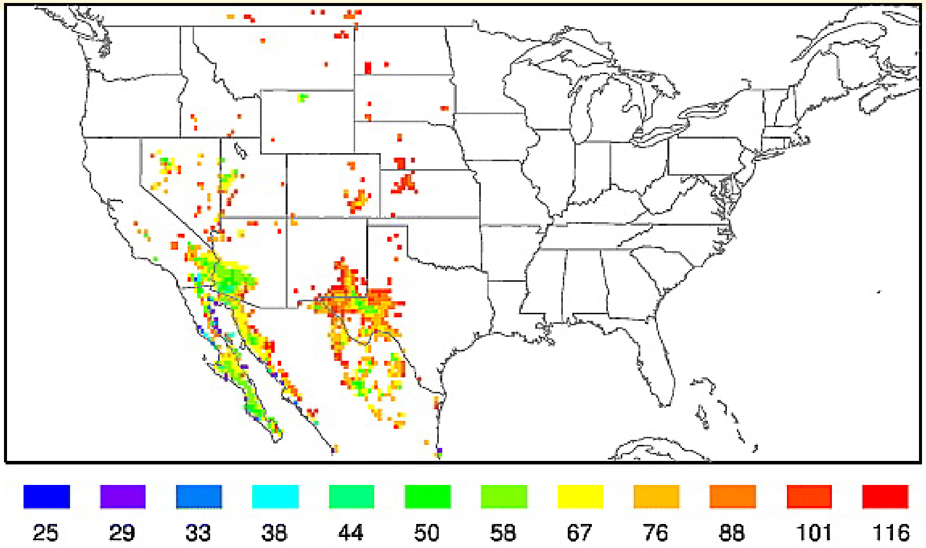
Globally: 25% landuse dust relatively constant; Hemispheric asymmetry with large variability

Major Uncertainties: Model physics

- Each model has its own physics for emission, transport and deposition
- With same sources, dust distribution will vary between models (see Huneeus et al., Atmos. Chem. Phys. 2011)

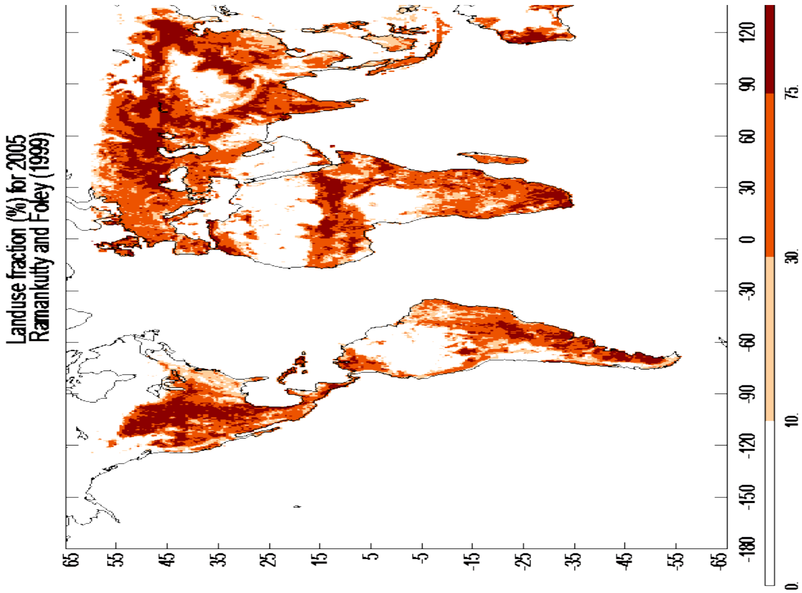
Major Uncertainties: Threshold of wind erosion

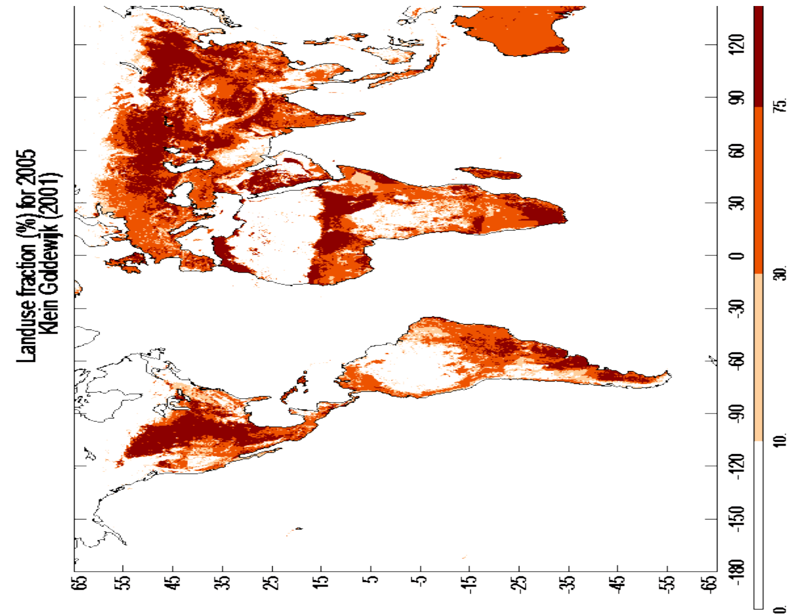
- Ut depends on soil moisture (weather but also irrigation), vegetation cover, harvesting litters
- Knowing daily M-DB2 DOD, Ut can be defined as the velocity that has the same frequency of as the 0.75 AOD *(Draxler et al., J. Geophys. Res., 2010)*. Problem: the work is limited to the US.
- To estimate anthropogenic contribution to global dust emission, Ginoux et al. (Rev Geophys., 2012) is using fixed values Ut= 6 m/s for natural dust, and 10 m/s for anthropogenic dust based on *Draxler et al. (J. Geophys. Res., 2010)*



Annual average threshold friction velocity (cm s−1) from *Draxler et al., J. Geophys. Res., 2010)*

Major Uncertainties: Landuse





Major difference in landuse fraction in Saudi Arabia, East Asia and Australia

If using threshold of landuse fraction: which value?

Anthropogenic Dust Experiment

- Objectives:
  - Estimate variability of anthropogenic dust emission, load, optical depth, and radiative fuxes

Models: transport or climate models with/without nudging

Period to simulate: 2010-2012 with spin-up

Anthropogenic Dust Experiment cont'd

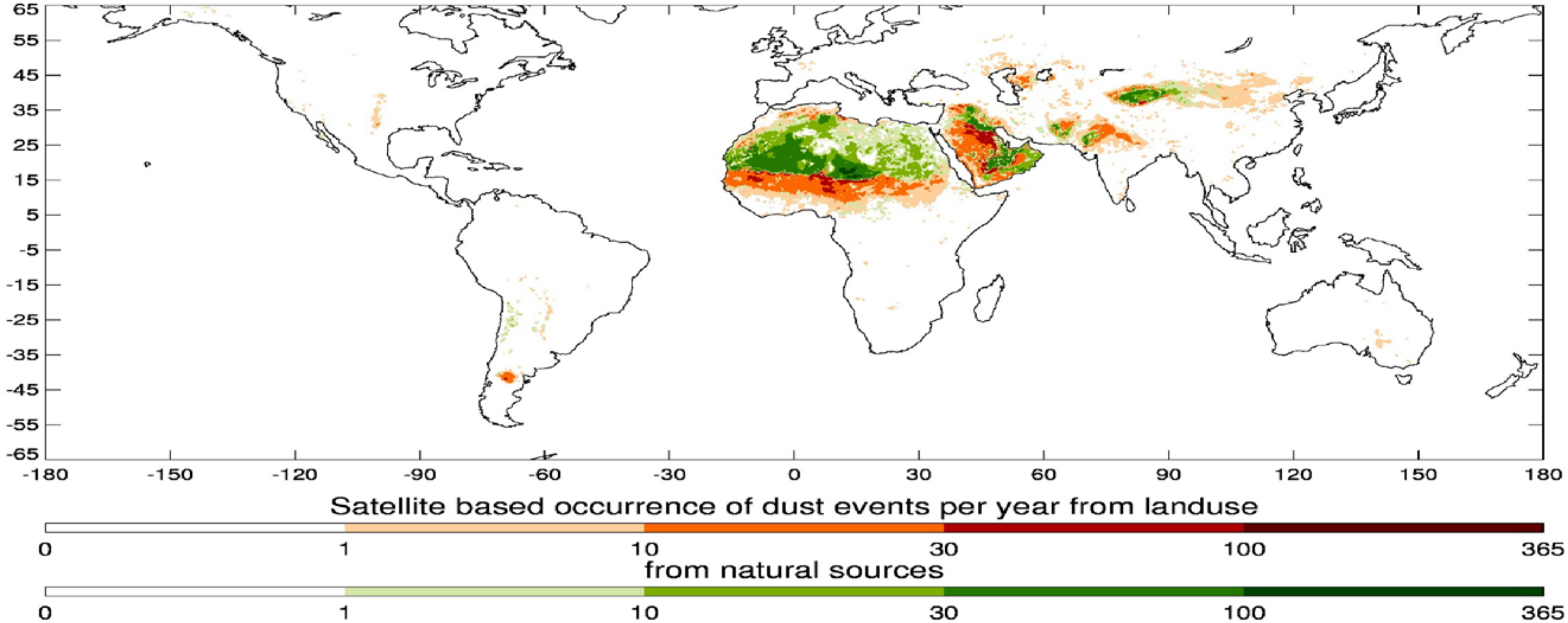
- Experiments:
  1. Simulate with your own sources and emission scheme
  2. Simulate with MDB2 natural sources with your own emission scheme for one year. Tune to have same emission has Exp 1
  3. Simulate with MDB2 natural sources with your own scheme "tuned" emission scheme
  4. Simulate with MDB2 anthropogenic sources with
     1. ½, 1, and 2 times threshold of wind erosion,
     2. Klein Glodewijk and Ramankutty landuse datasets

Input data

- Time series from 2010 to 2012 of monthly MODIS Deep Blue based source fraction, as described in Ginoux et al. (Rev. Geophys. 2012) updated with Collection 6
- Time series of monthly masks: LAI (MODIS), soil moisture (AMSR-E), snow (MODIS)
- Landuse fraction from Klein Goldewijk and Ramankutty
- Resolution: 1x1 and 0.25x0.25
- Format: netcdf

MODIS based dust sources

- Dust Optical Depth (DOD) derived from daily MODIS-DB level-2 C6 aerosol products (AOD(λ), QA, and SSA) from 2003-2014 (Hsu et al., 2003; Sayer et al., 2013)
- Frequency of Occurrence (FoO) of DOD>0.2 per year over 12 years = dust sources
- Anthropogenic sources = FoO>0 and landuse>30% (landuse dataset for 2005 from *Klein Goldwijk (2001*)

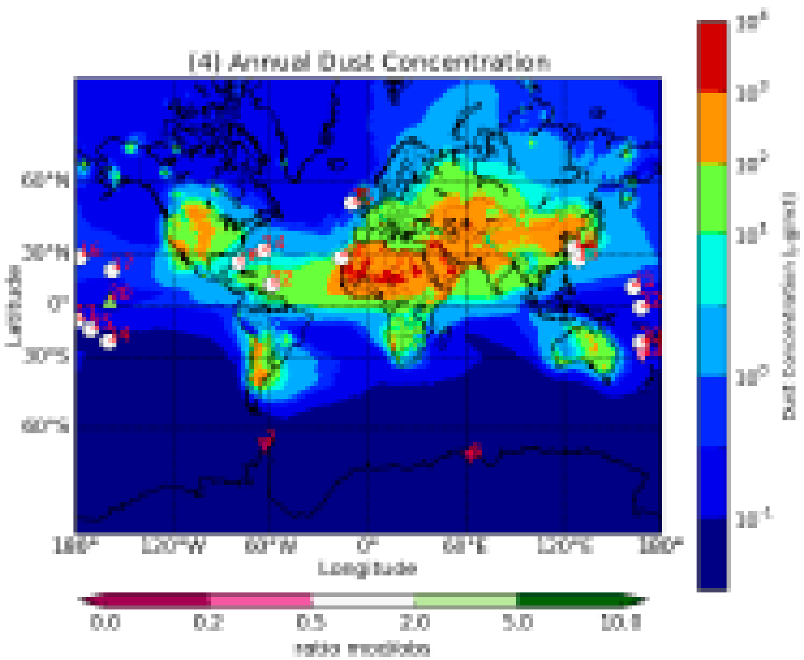


Ginoux et al., Rev. Geophys., 2012

Deliverable: Evaluation with obs

Comparison with :

- surface concentration (U. Miami, LISA, IMPROVE, others if available)
- AERONET SDA coarse mode AOD
- MODIS Deep Blue
- CALIOP



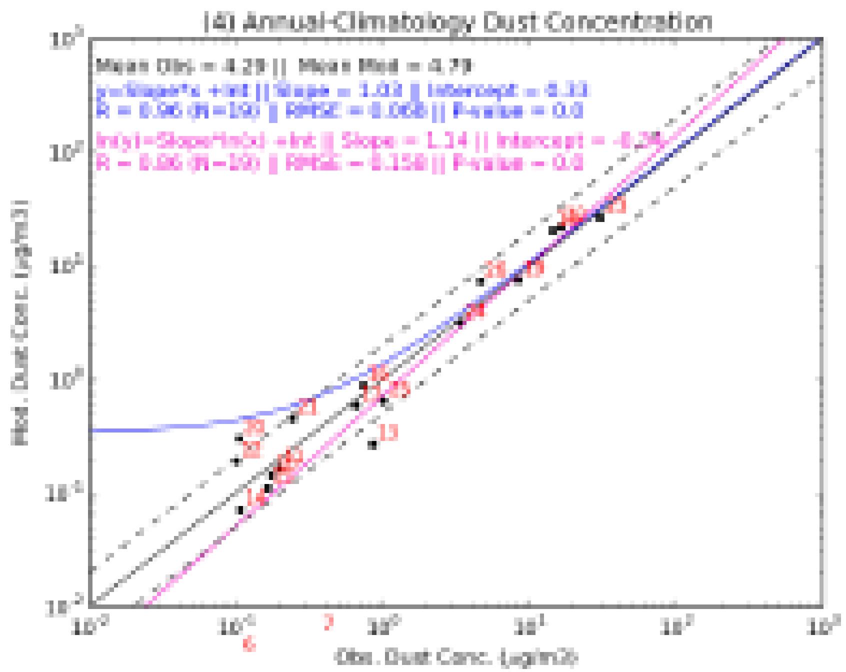


Figure generated by A. Deroubaix

Deliverable: Budget

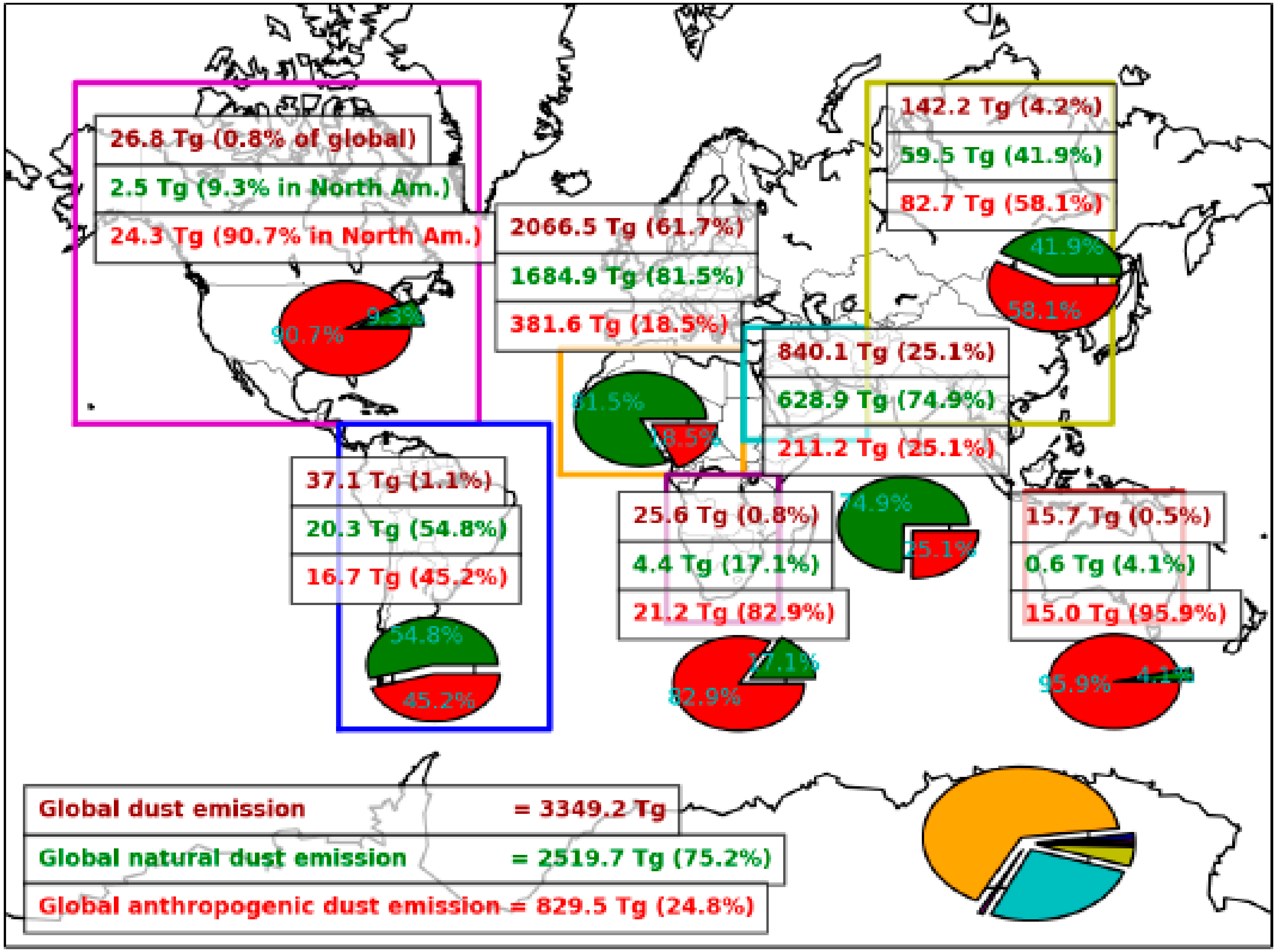


Figure generated by A. Deroubaix

Deliverables: DOD and RF

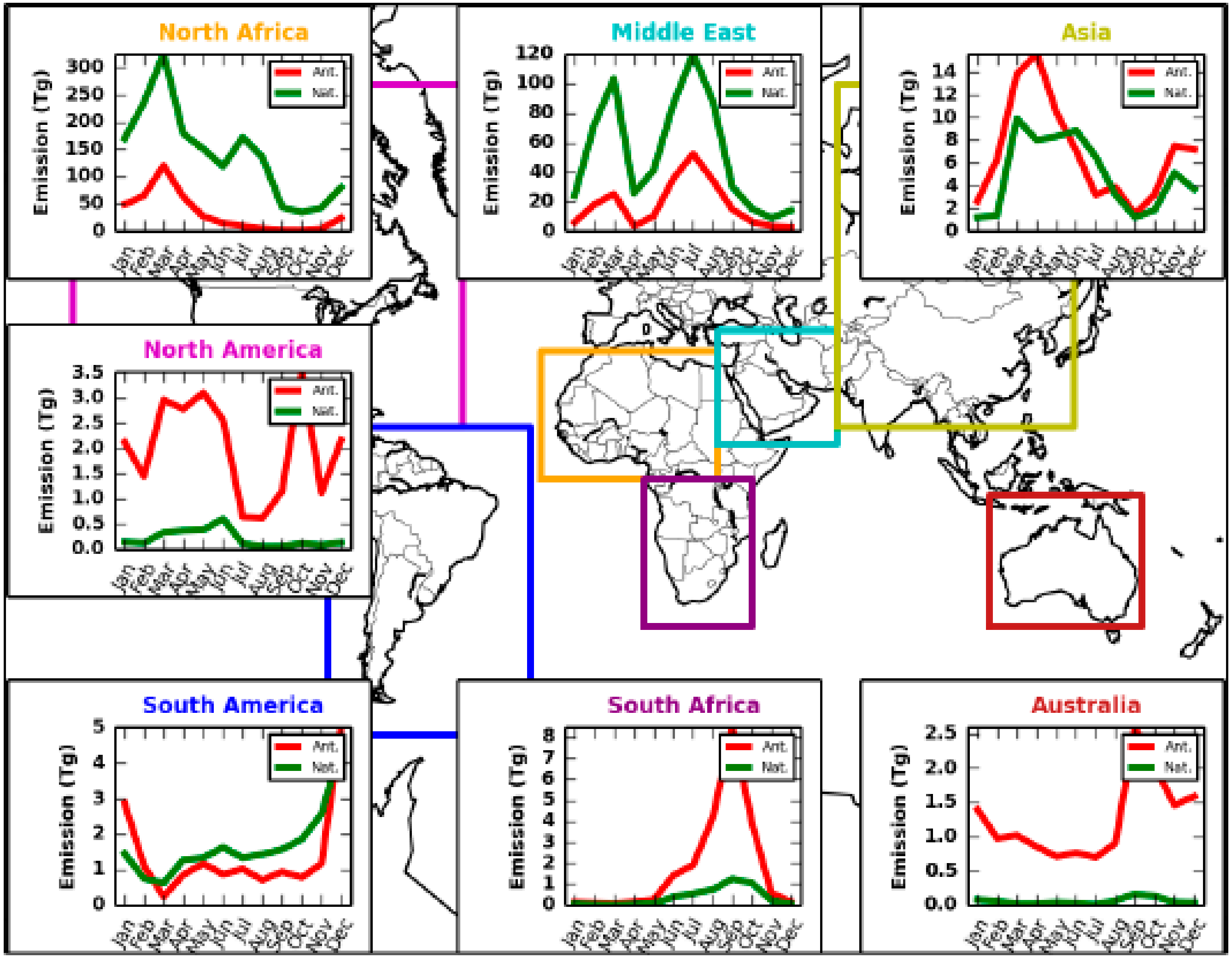


Figure generated by A. Deroubaix

Requested Diagnostics

- **Static:** model grid, altitude ASL, land/sea mask, dust size properties: functional distribution, min/max and effective radii, density
- **2-D daily:**
  - Surface pressure
  - Maximum surface wind (friction and/or 10-meter)
  - Model masks if used for dust emission (LAI, soil moisture, snow,…)
  - For each dust bins:
    - Emission
    - Deposition (wet and dry)
    - Dust mass column
    - Optical depth at 550 nm
    - Absorption optical depth at 550nm
- **3-D daily:**
  - For each dust size bins: dust concentration