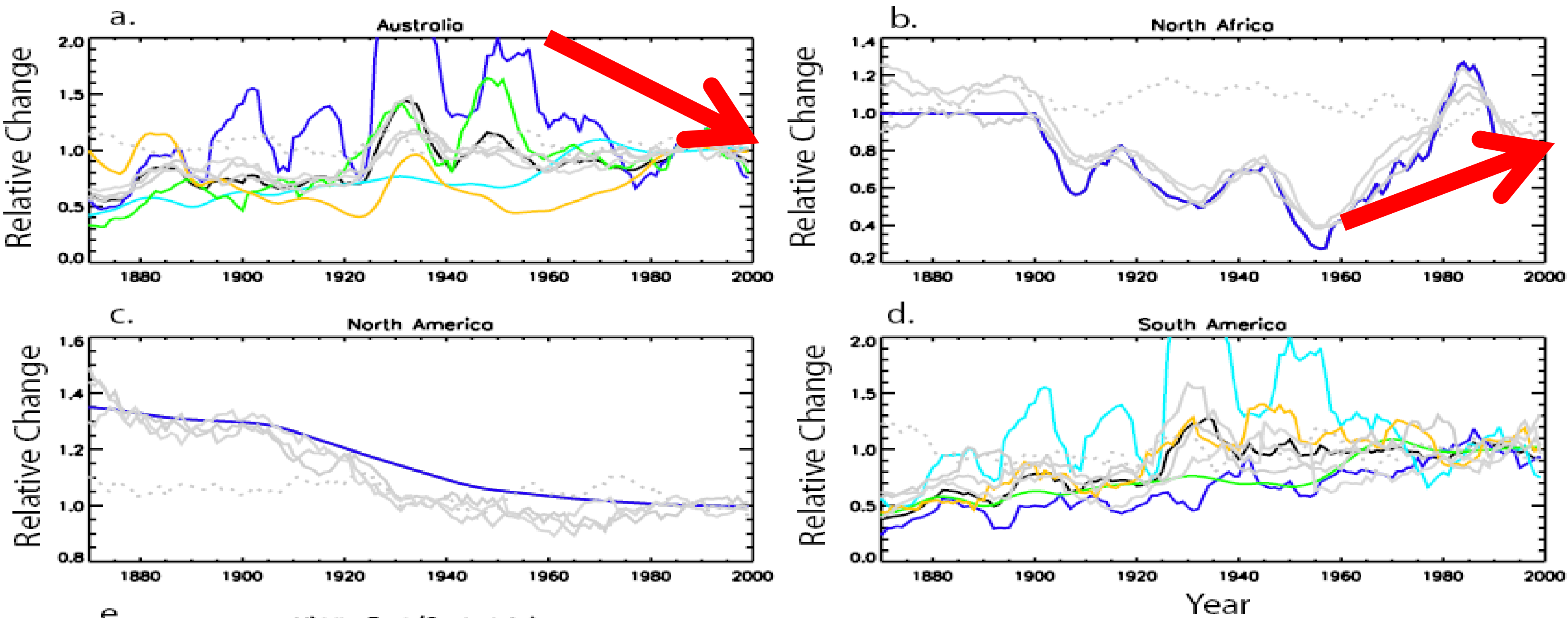
Modeling Long-term Variability of Dust

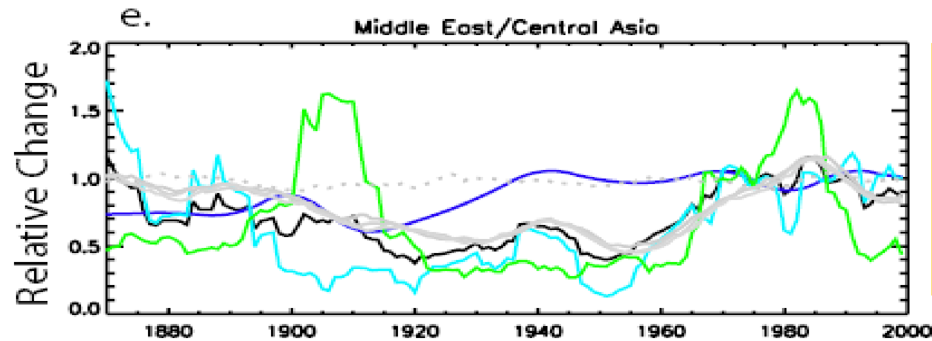
Paul Ginoux[1], Sergey Malyshev[2], and Elena Shevliakova[2]

1. NOAA/GFDL, Princeton, NJ,USA
2. Princeton University, NJ, USA

AerocCom XII
September, 2013

Measured dust deposition relative to present

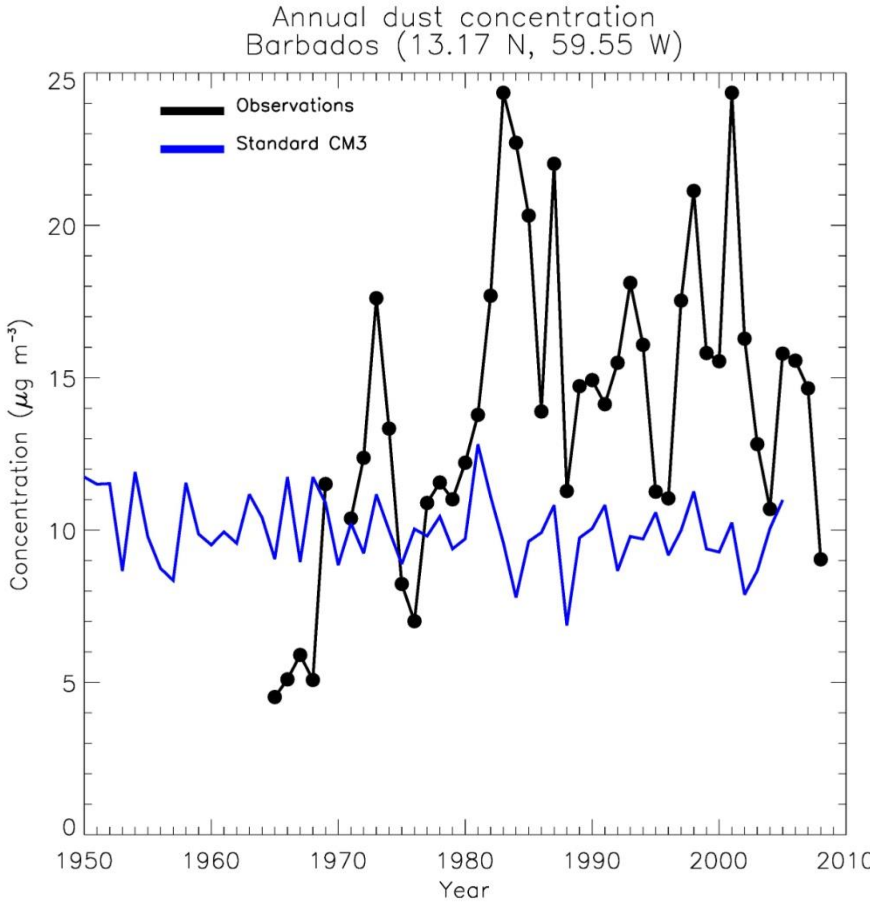


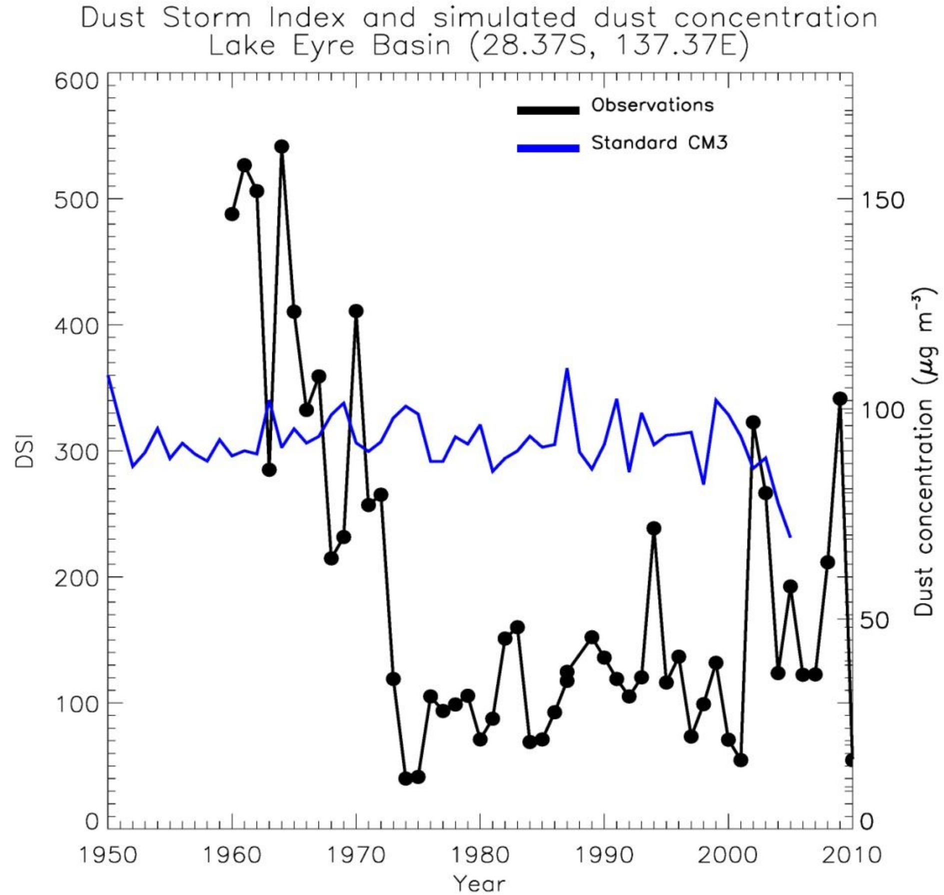


Dust deposition varies by a factor 2, increasing in N Africa and decreasing in Australia, since 1960.

Mahowald et al., Atm. Chem. Phys., 2010

Comparison simulated and observed dust





GFDL (and all others) climate models fail to reproduce observed decadal variation of dust.

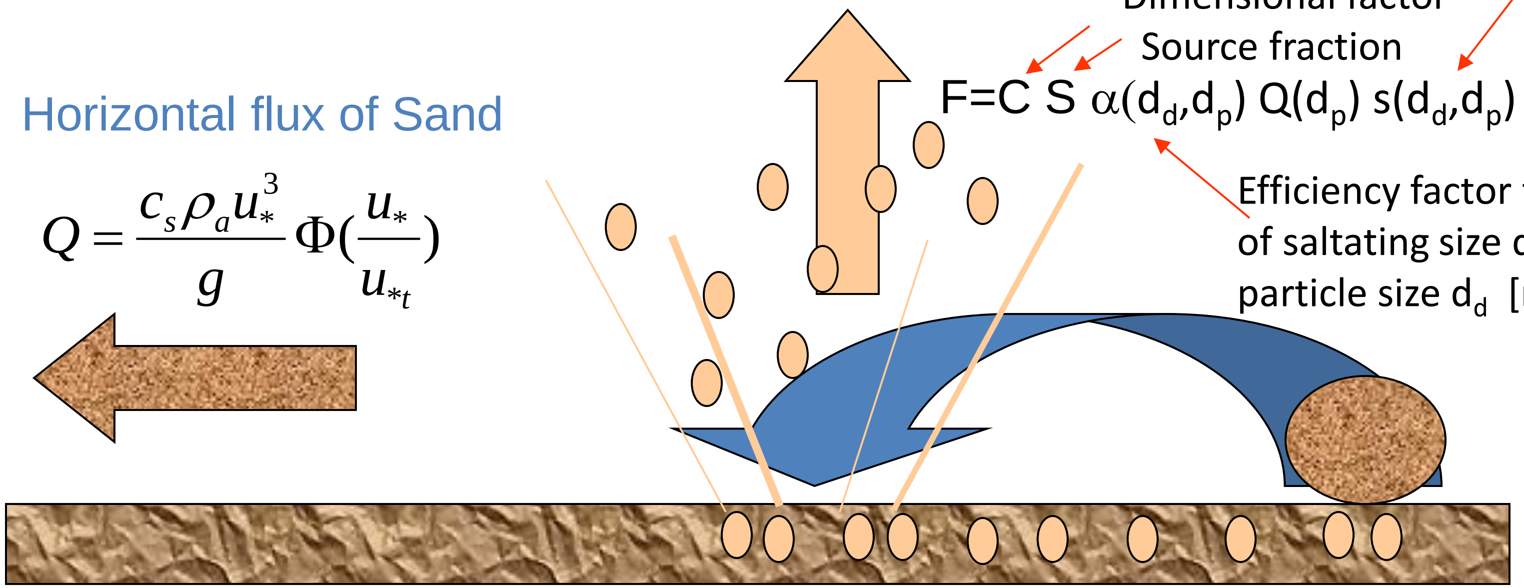
Dust emission

Vertical Flux of clay and silt

$$F = C\ S\ \alpha(d_d, d_p)\ Q(d_p)\ s(d_d, d_p)$$

Horizontal flux of Sand

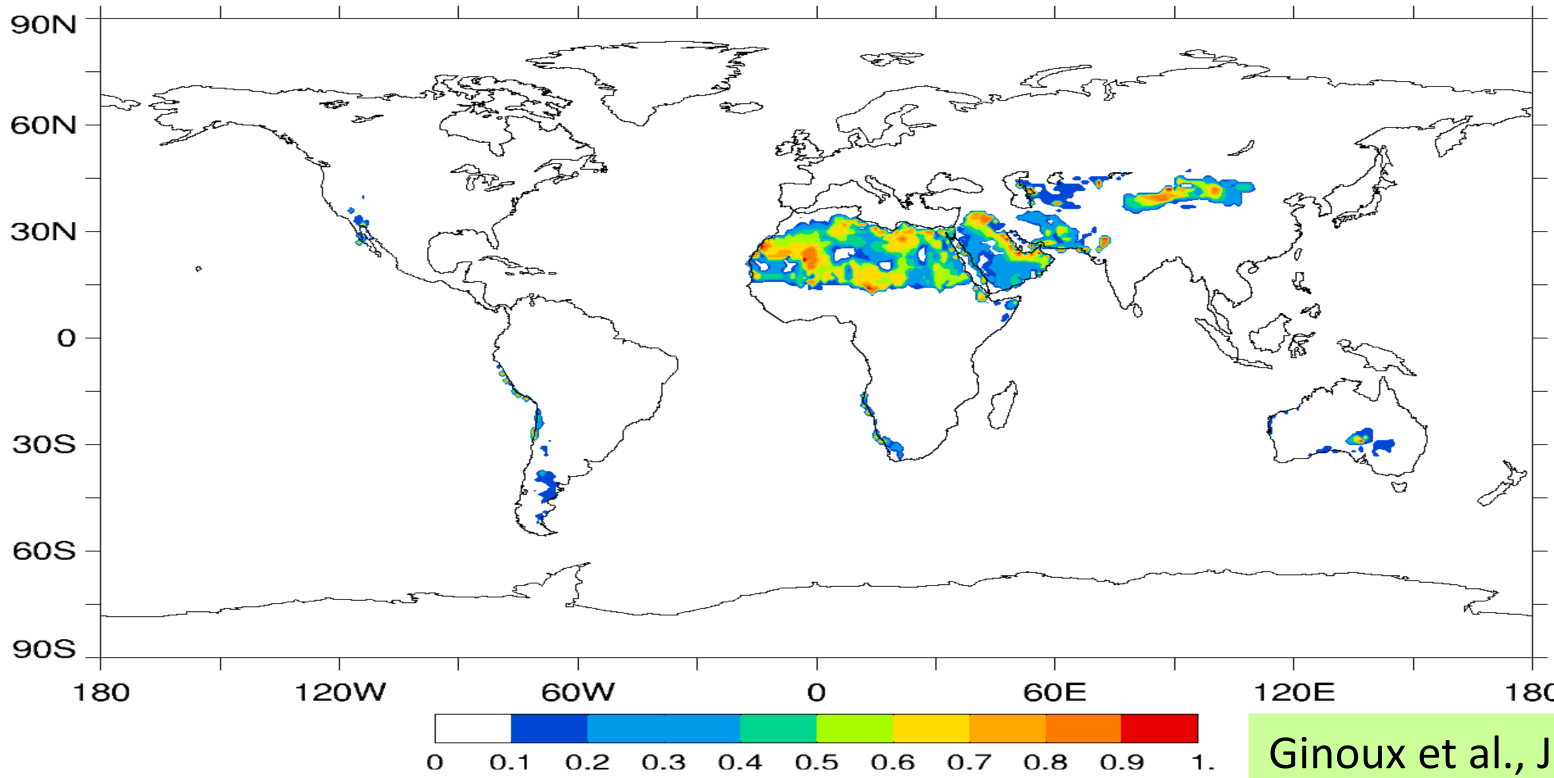
$$Q = \frac{c_s \rho_a u_*^3}{g} \Phi\left(\frac{u_*}{u_{*t}}\right)$$



Not only u* varies in time but also S due to changes of vegetation cover and landuse.

u_*^3 may seem to control dust emission variability at all temporal scales, but this presentation will show that S is in fact controlling long-term variability.

Topography based dust sources

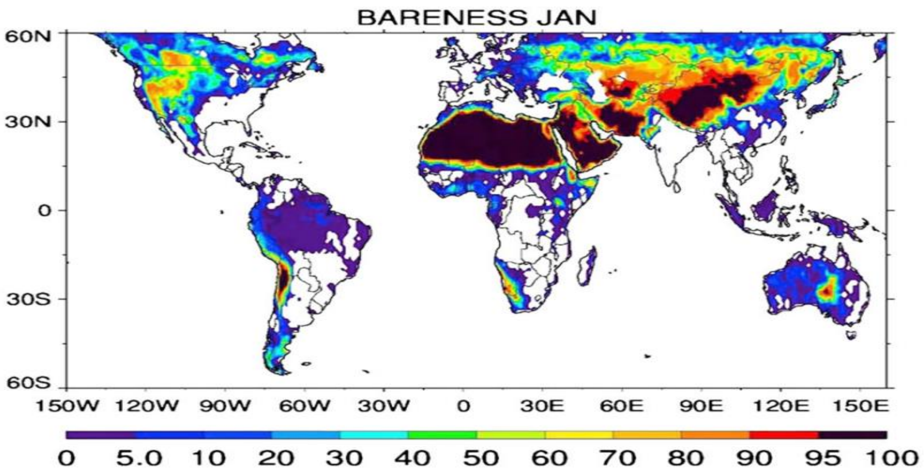


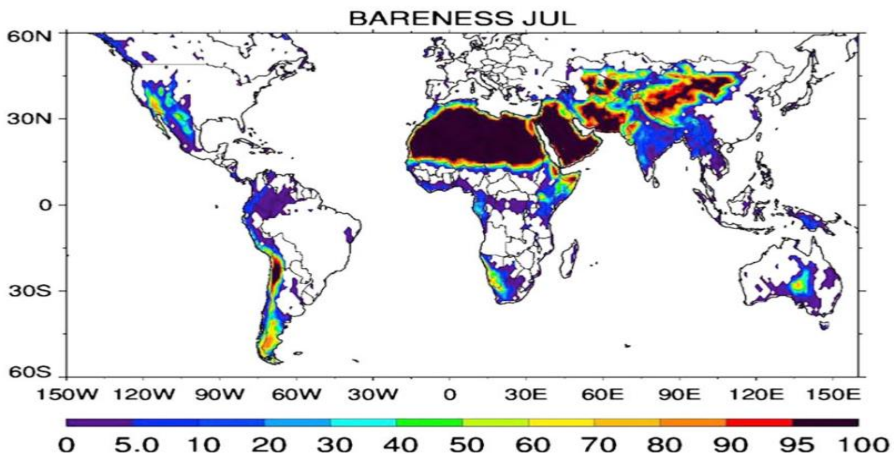
Ginoux et al., JGR, 2001

Dust sources are preferentially located in topographic depressions with bare surface (no vegetation). But vegetation cover varies with (among other factors) hydrological and landuse changes.

Are dust sources variation with vegetation important?

Bareness = AVHRR NDVI < 0.15

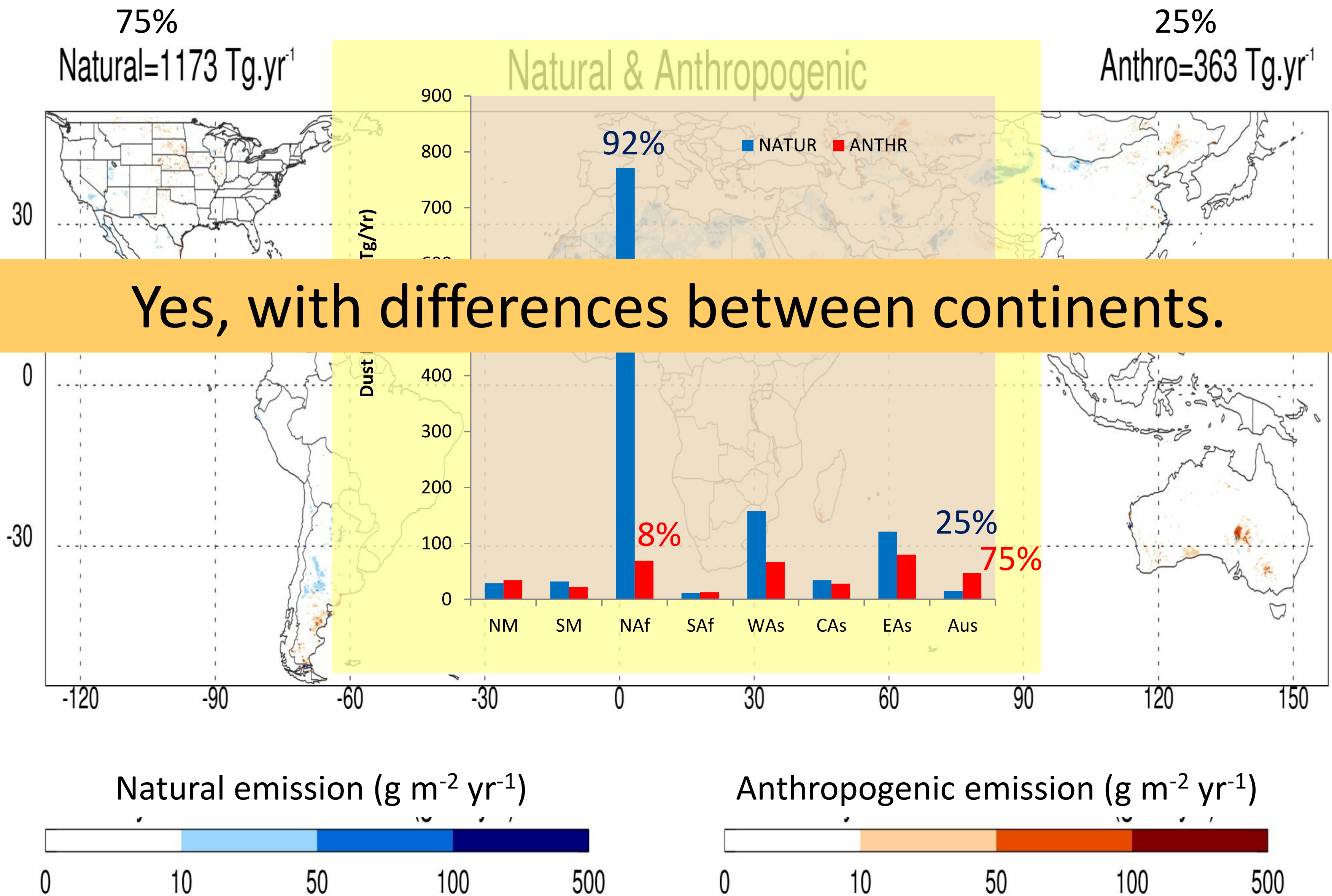




Kim et al., *J. Geophys. Res.*, 2013: Vegetated surfaces ~ 12%.

Yes, with difference between continents

Is dust from agriculture important?

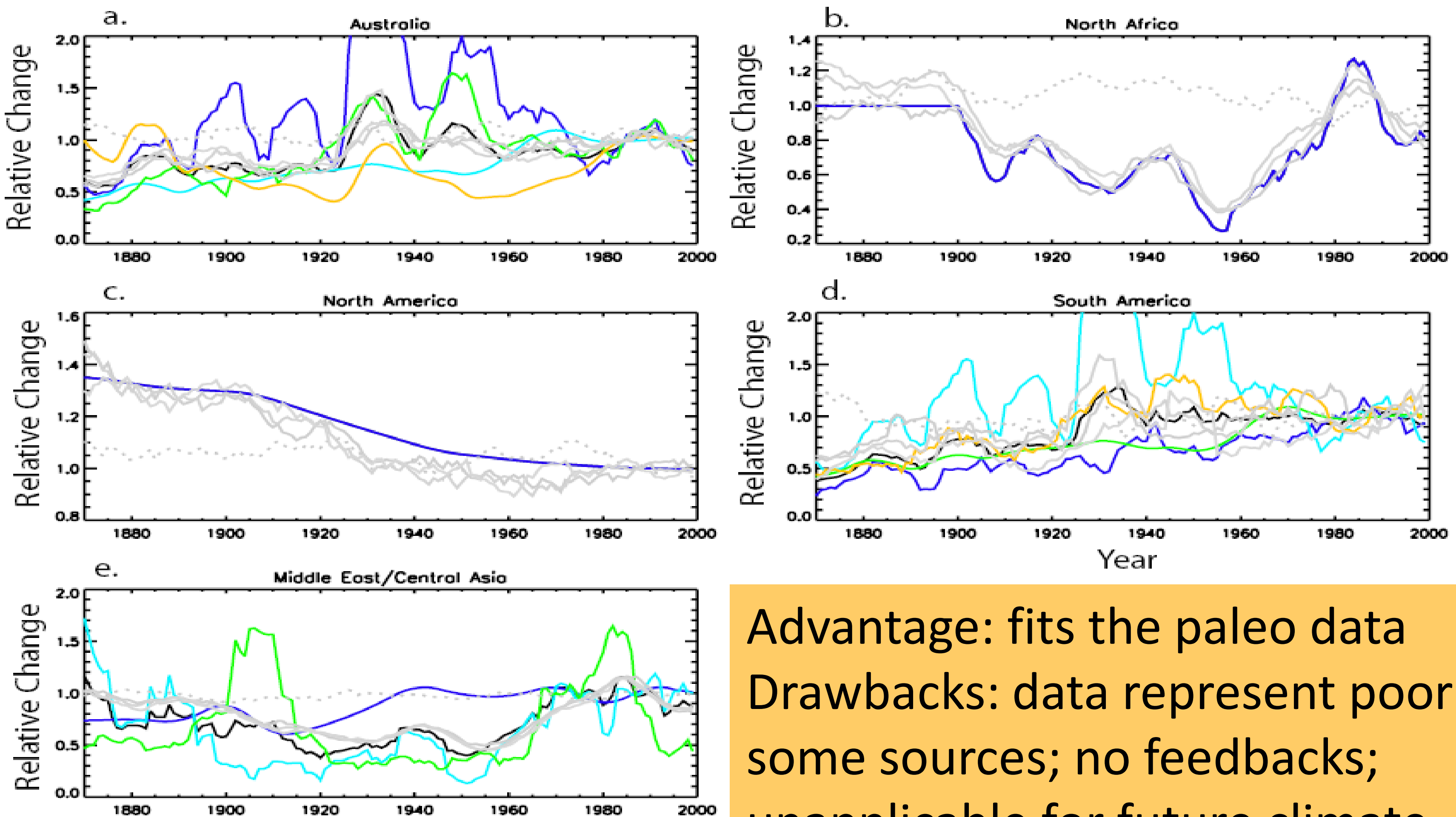


Yes, with differences between continents.

Ginoux et al., RoG, 2012

After 1979, global satellite data are available. For past climate only few paleo dust records.

Natalie's solution: impose change of source strength to fit paleo data.

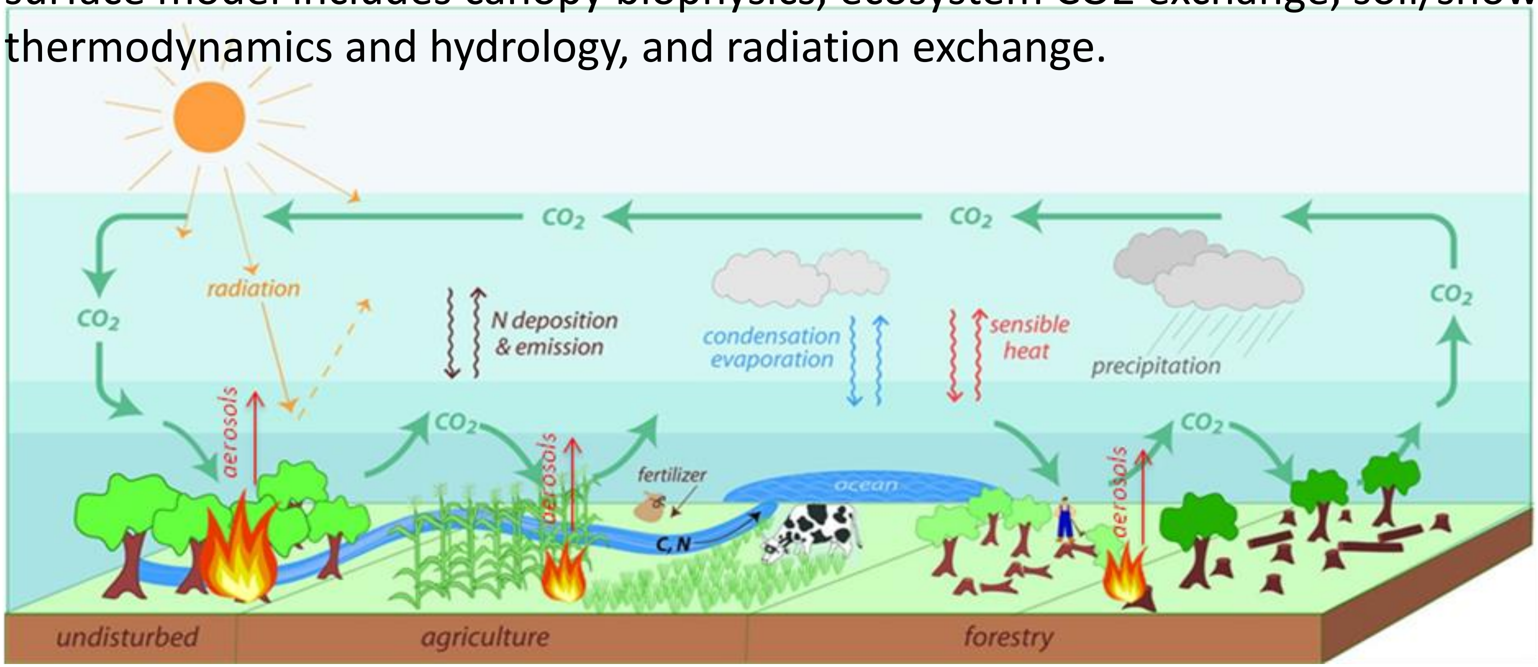


Mahowald et al., Atm. Chem. Phys., 2010

Advantage: fits the paleo data
Drawbacks: data represent poorly some sources; no feedbacks; unapplicable for future climate.

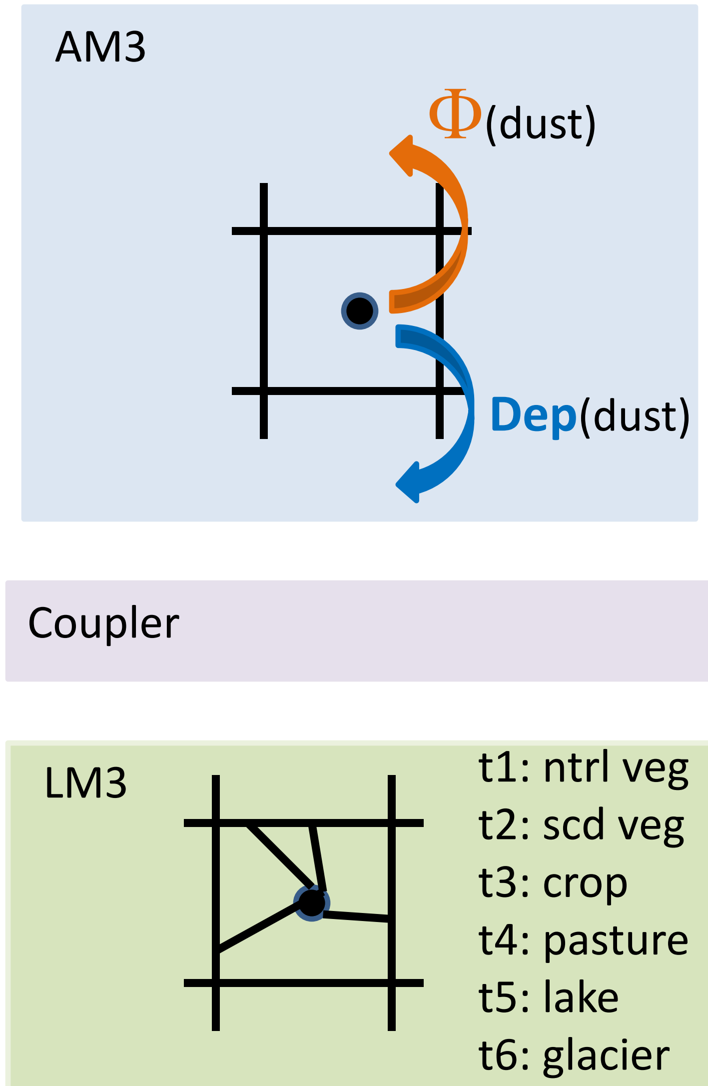
Implementation of dust emission in GFDL dynamic land model to include vegetation and landuse in emission parameterization

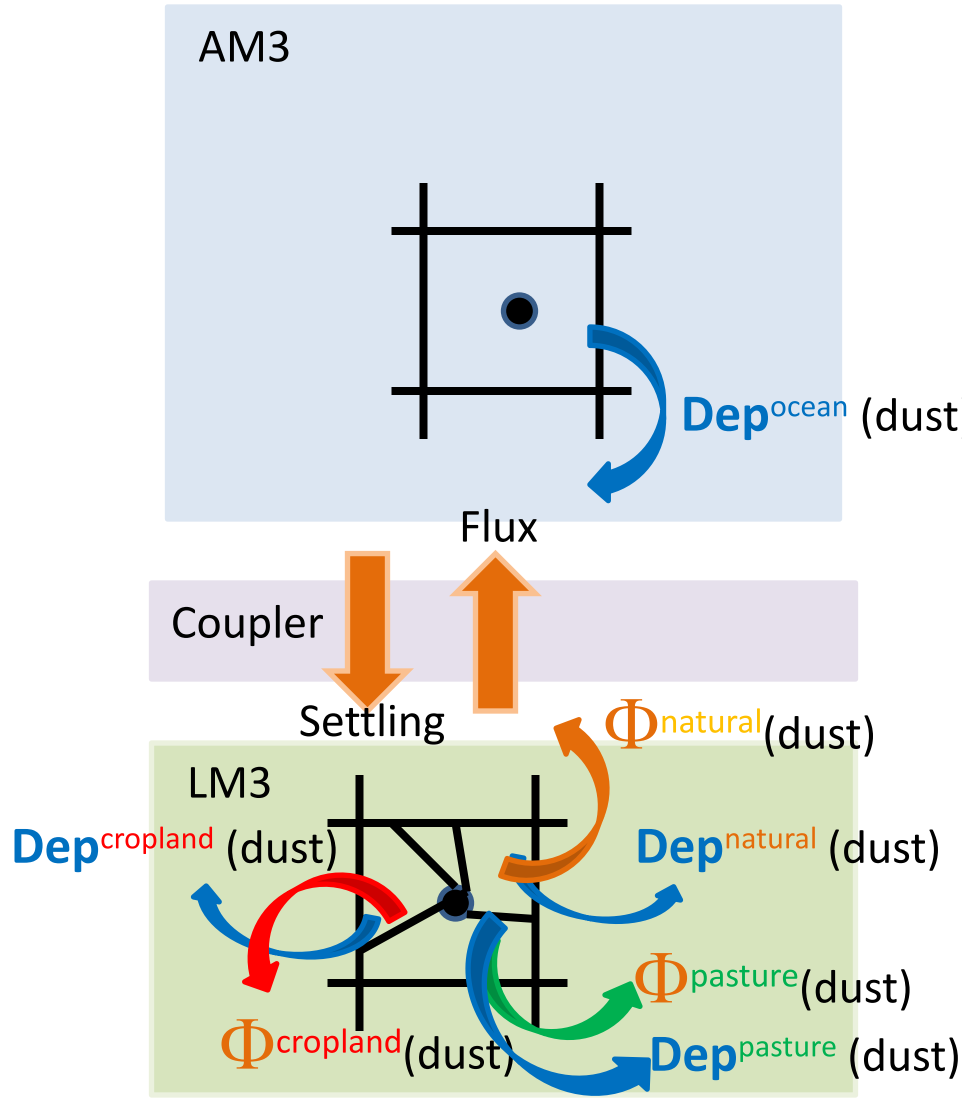
LM3 consists of two main components: a land surface model and a global dynamic vegetation model, which includes a representation of changing land-use practices (Shevliakova et al. 2009). The distribution of croplands and pastures as well as wood harvesting are prescribed from land-use transition dataset (Hurtt et al. 2006; 2009). The state of primary and secondary land cover is treated prognostically. The land surface model includes canopy biophysics, ecosystem CO2 exchange, soil/snow thermodynamics and hydrology, and radiation exchange.



Static dust sources

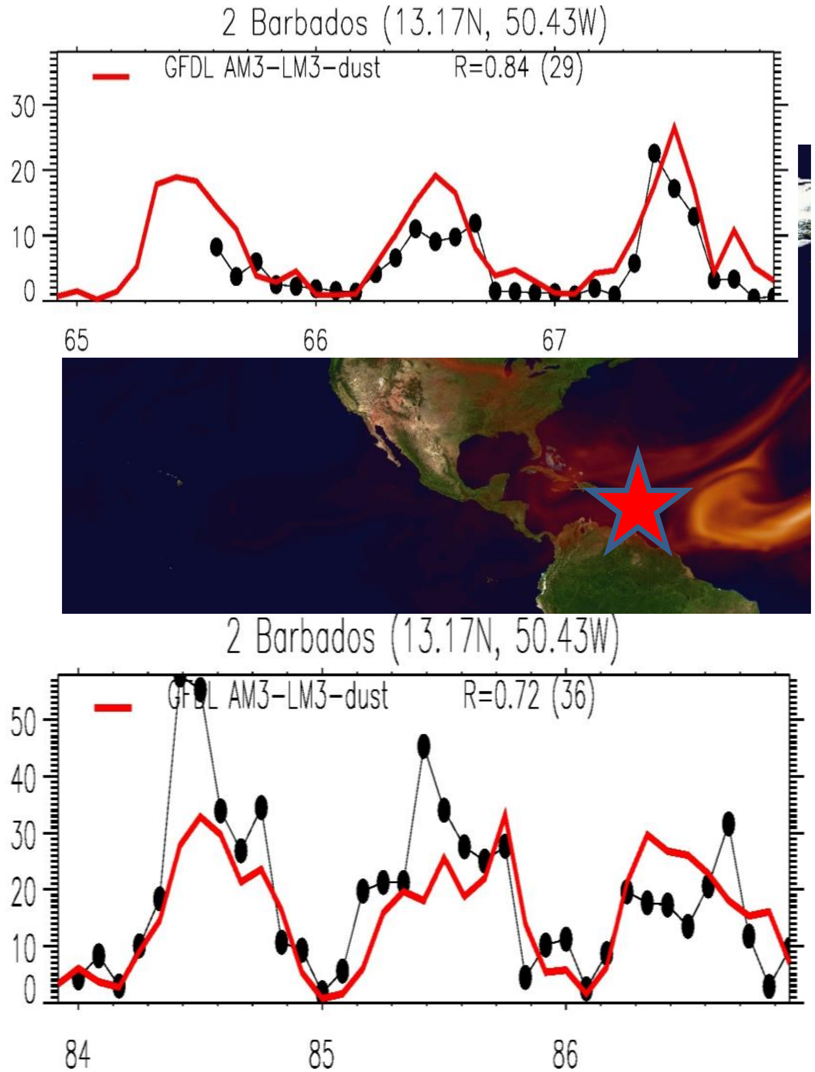
Dynamic natural, cropland, pasture dust emissions and depositions

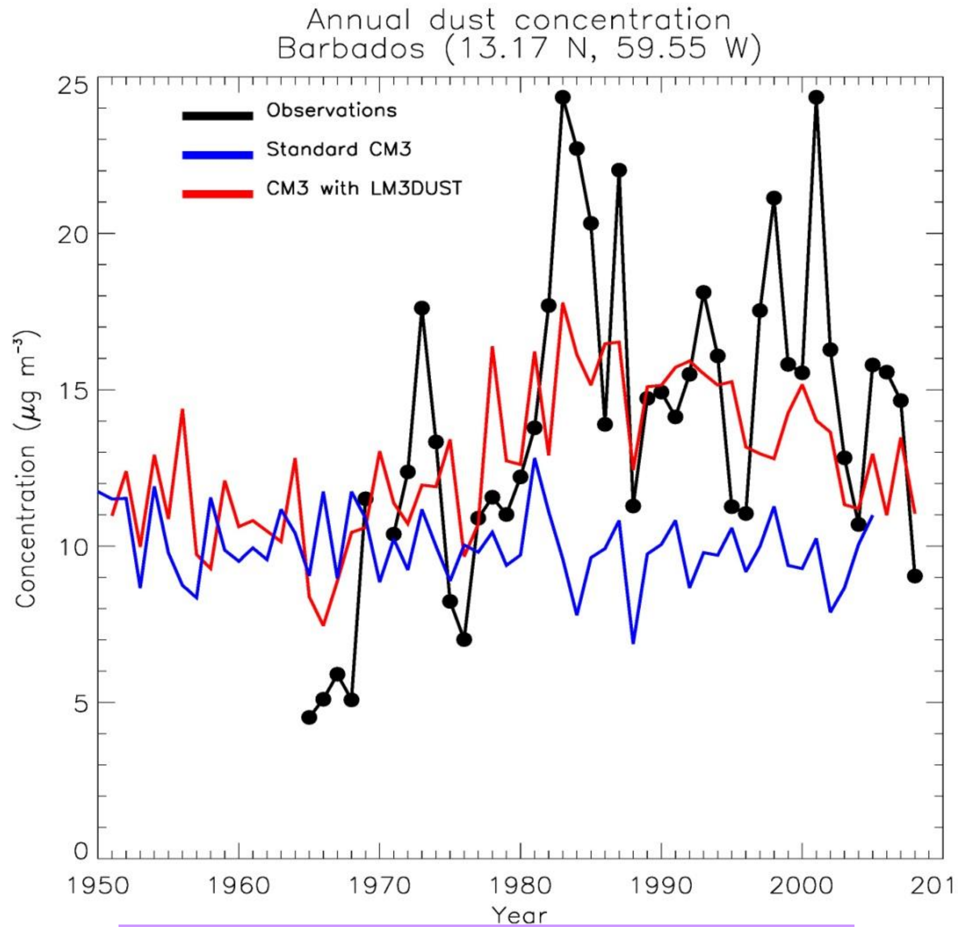




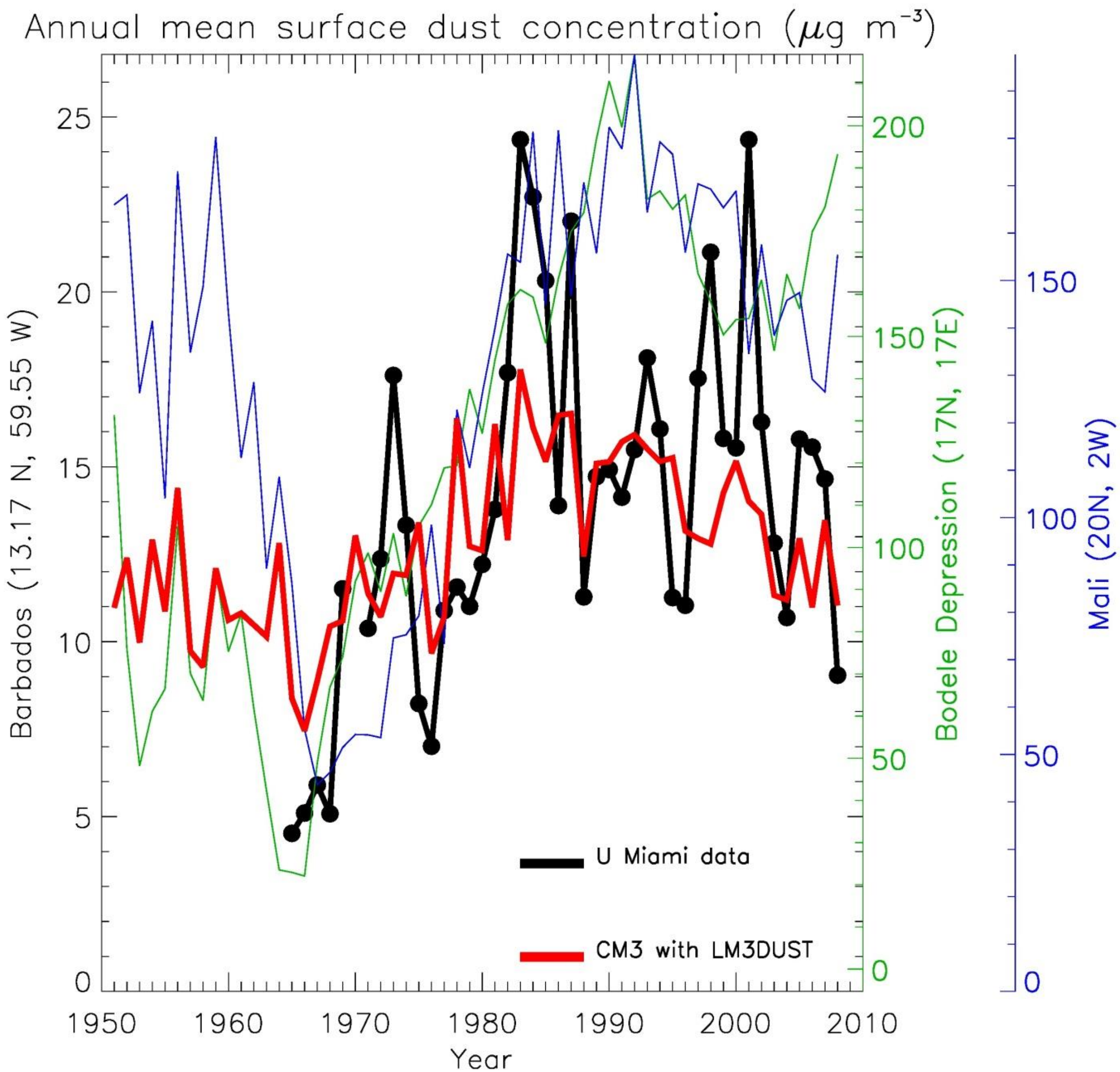
New vertical level within the canopy

Comparison with Barbados data



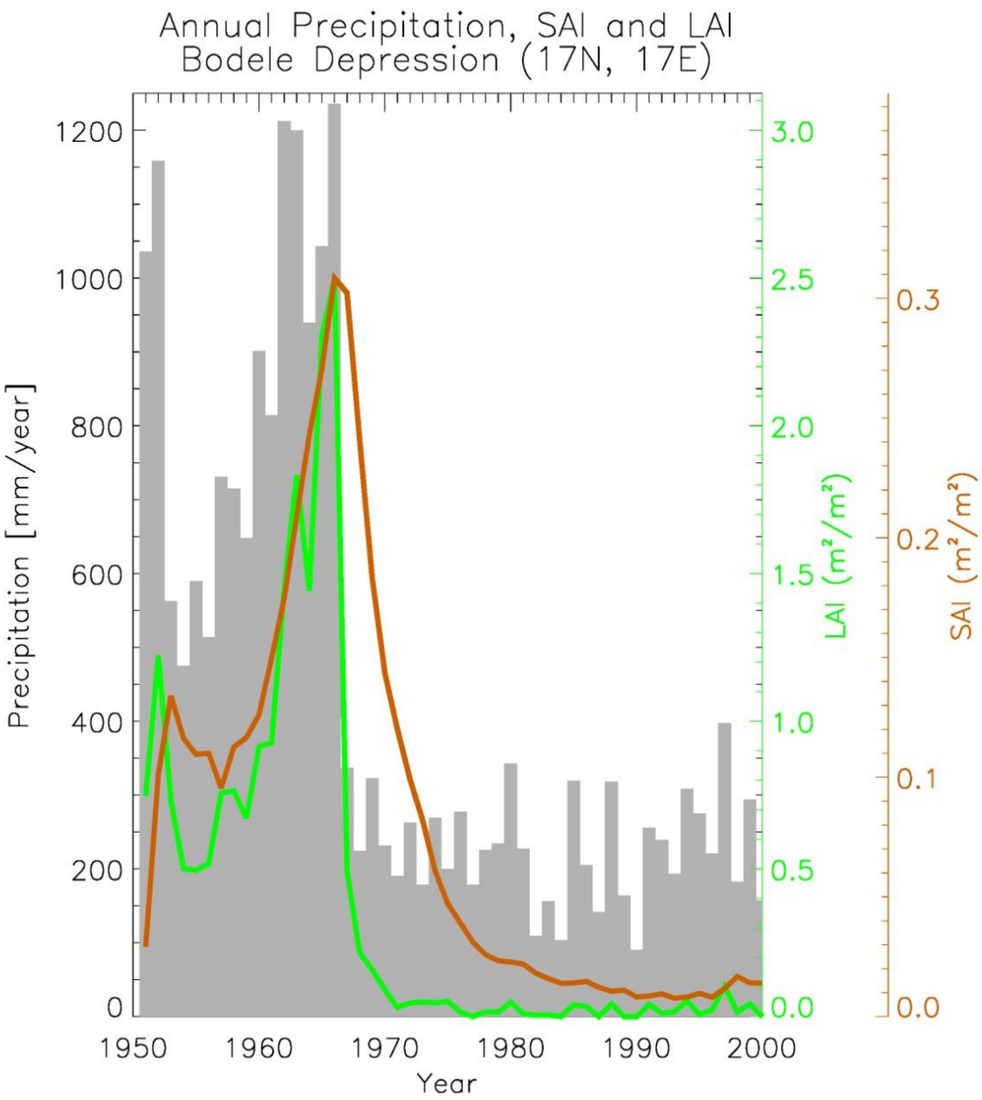


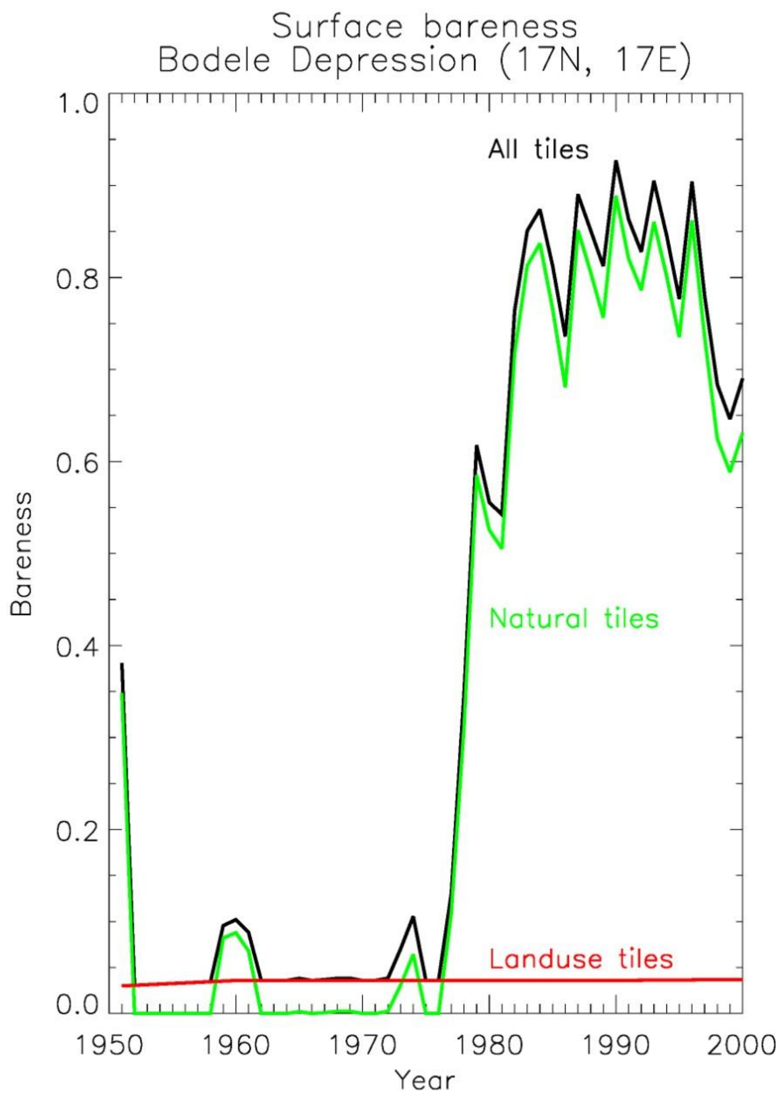
LM3dust captures factor 2 changes between the 60ies and 80ies, although too high in 60s too low in 80s



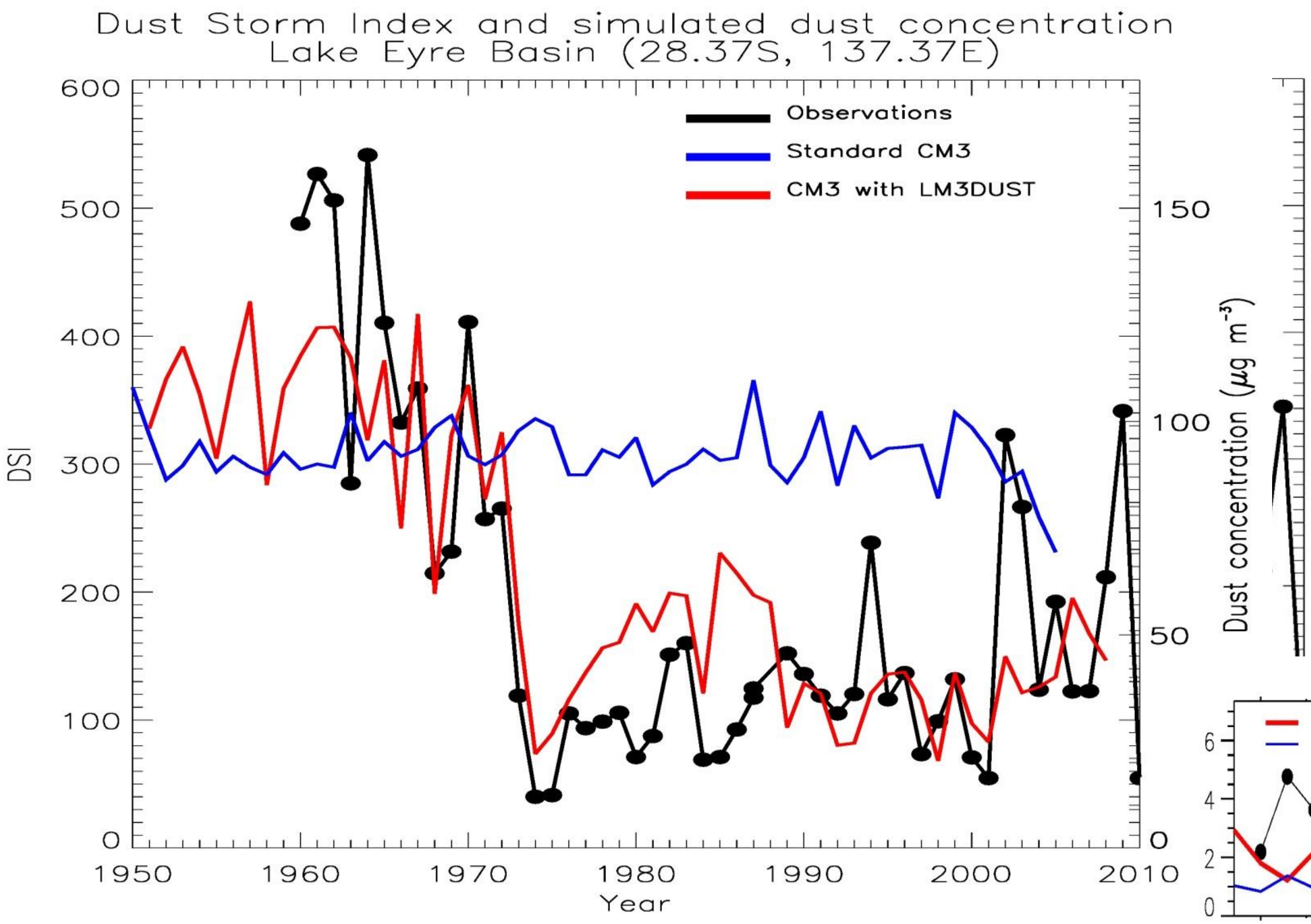
Model at Barbados is only a factor 2 compare to 4 for obs and African sources

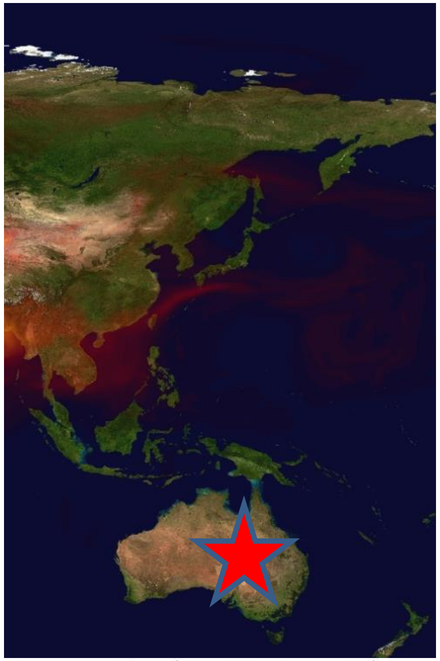
Time series of precip, SAI, LAI and bareness

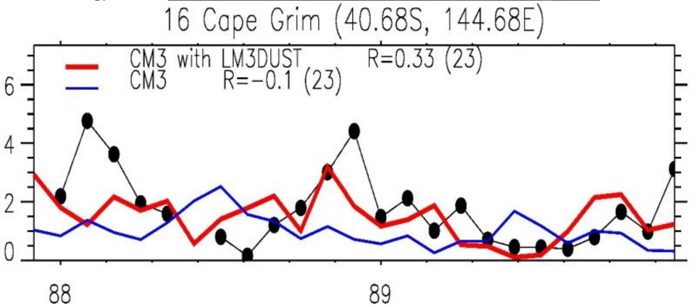




Comparison with Lake Eyre Basin (Australia) data



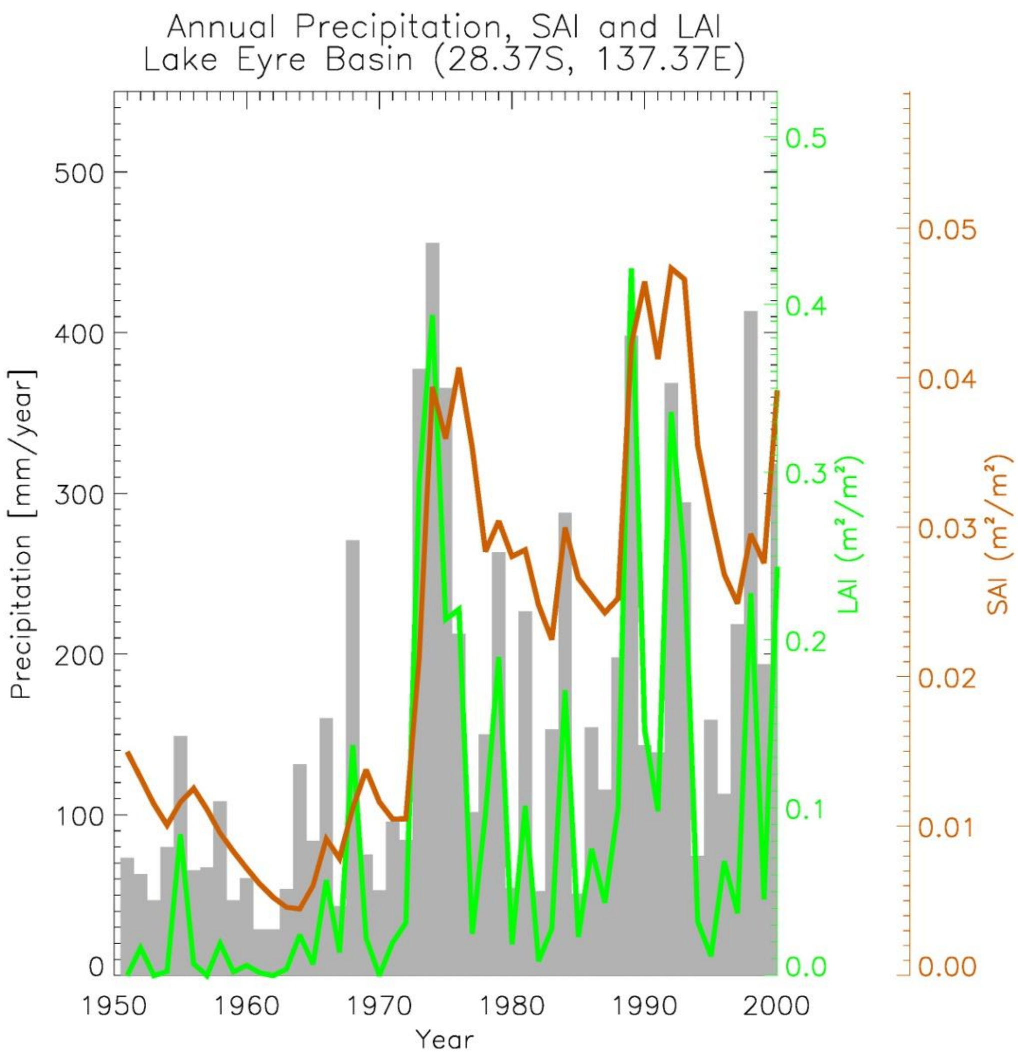


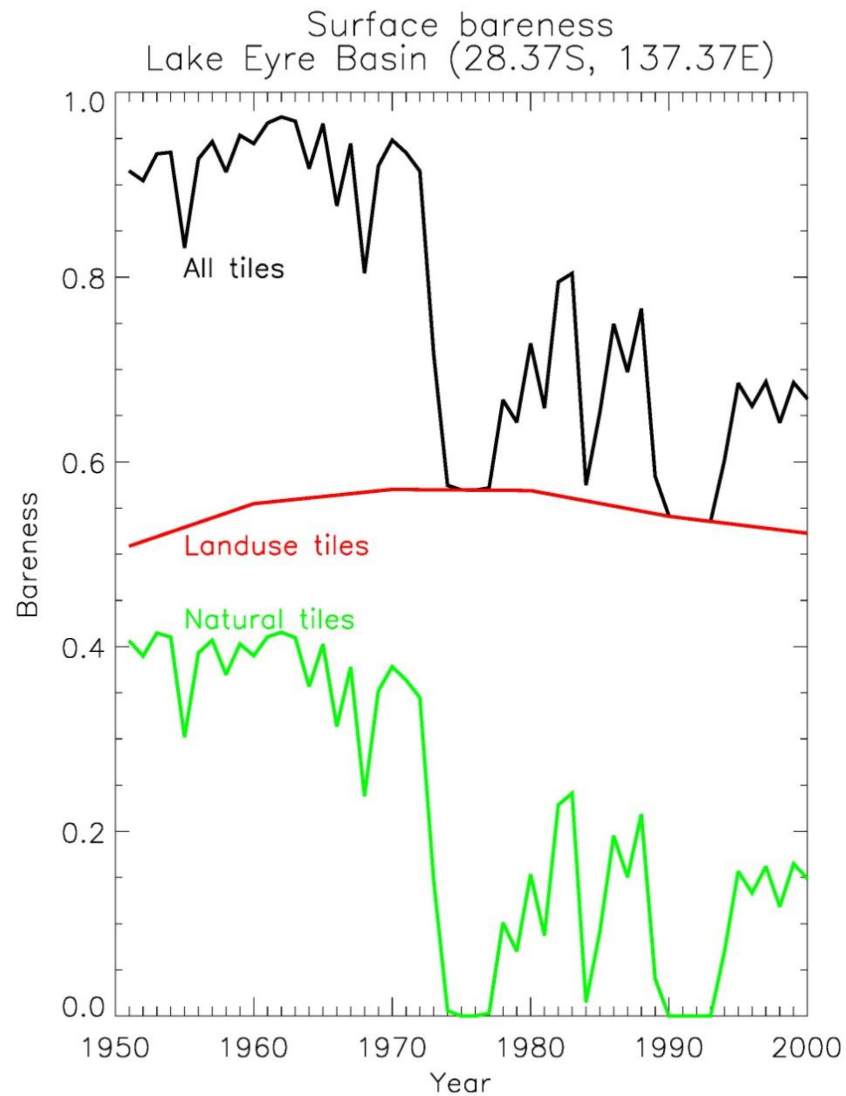


Strong et al., 2010

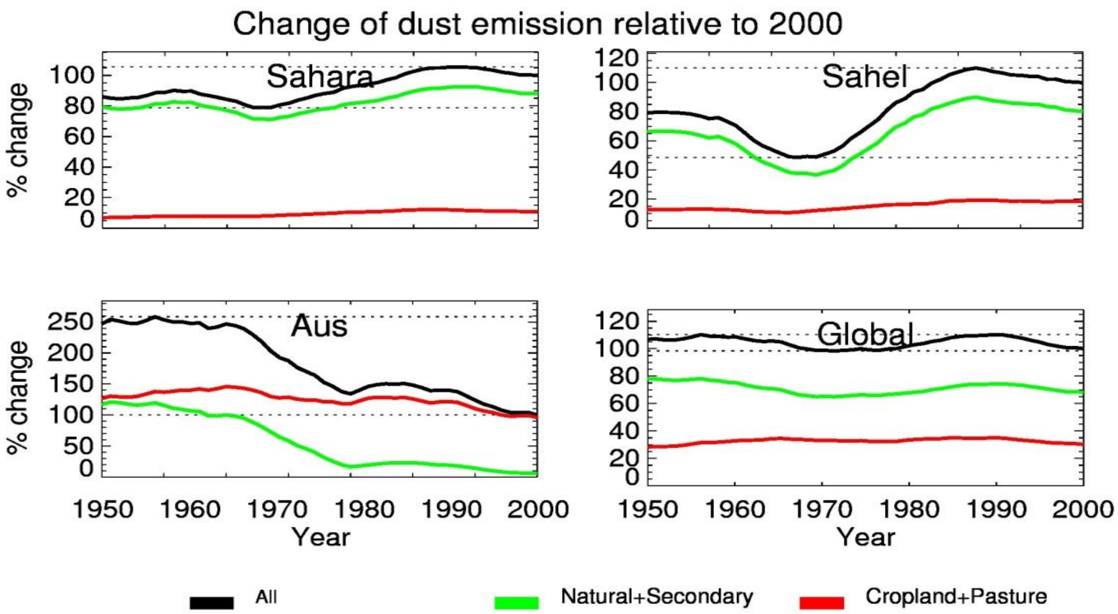
Following heavy precipitation in early 70ies, surface dust concentration dropped by a factor 3 in agreement with Dust Storm Index.

Time series of precip, SAI, LAI and bareness





Changes (%) of dust emission relative to 2000: Natural/Anthropogenic

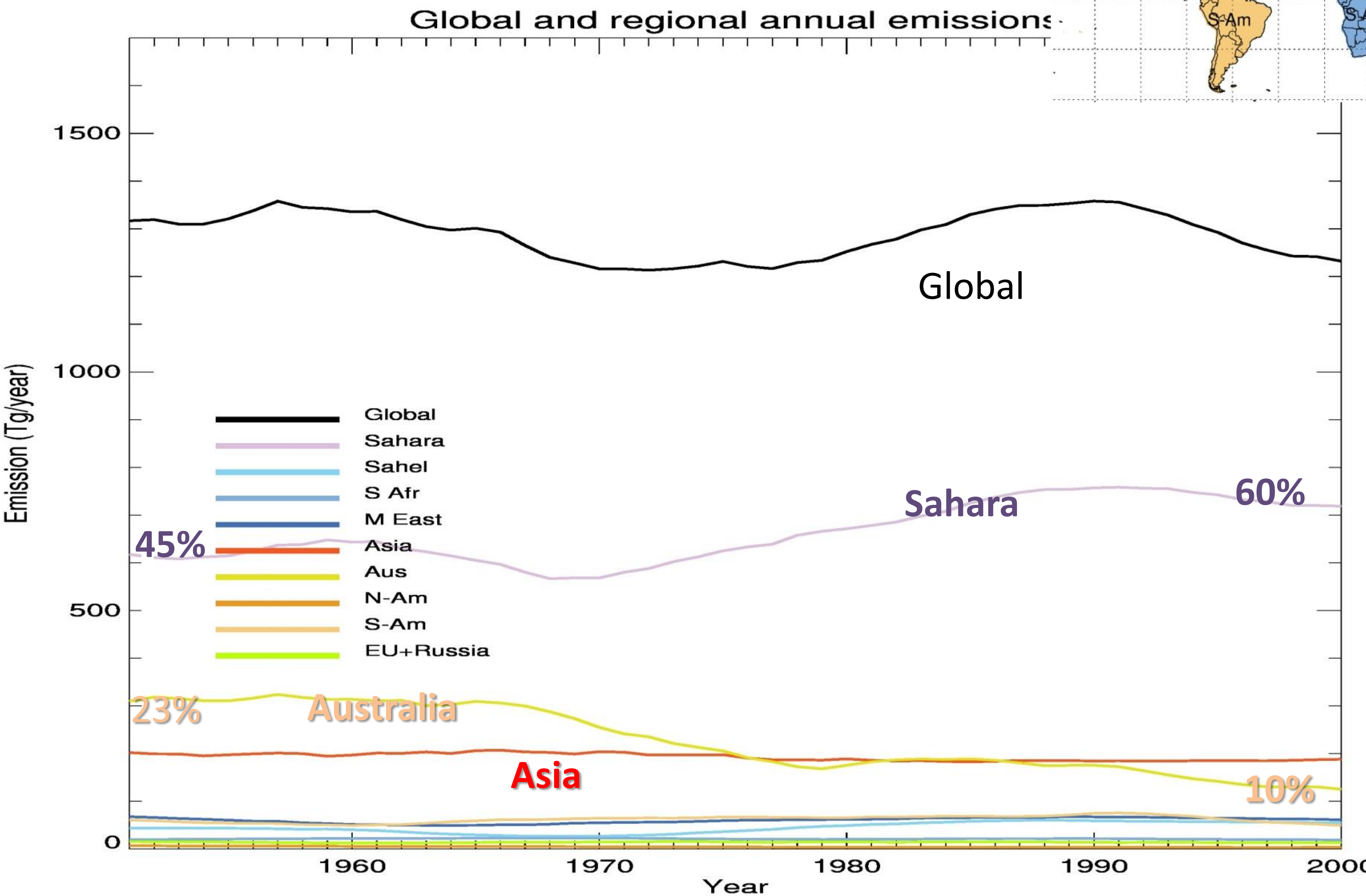


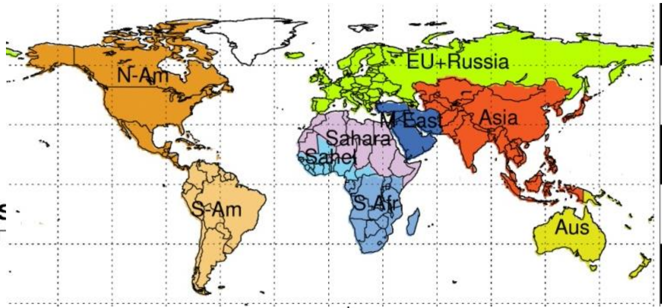
Sahara and Sahel: minimum in 1960ies due to vegetation change, anthro dust slightly increase

Australia: natural emission have decreased by 2.5, while anthropogenic dust is stable

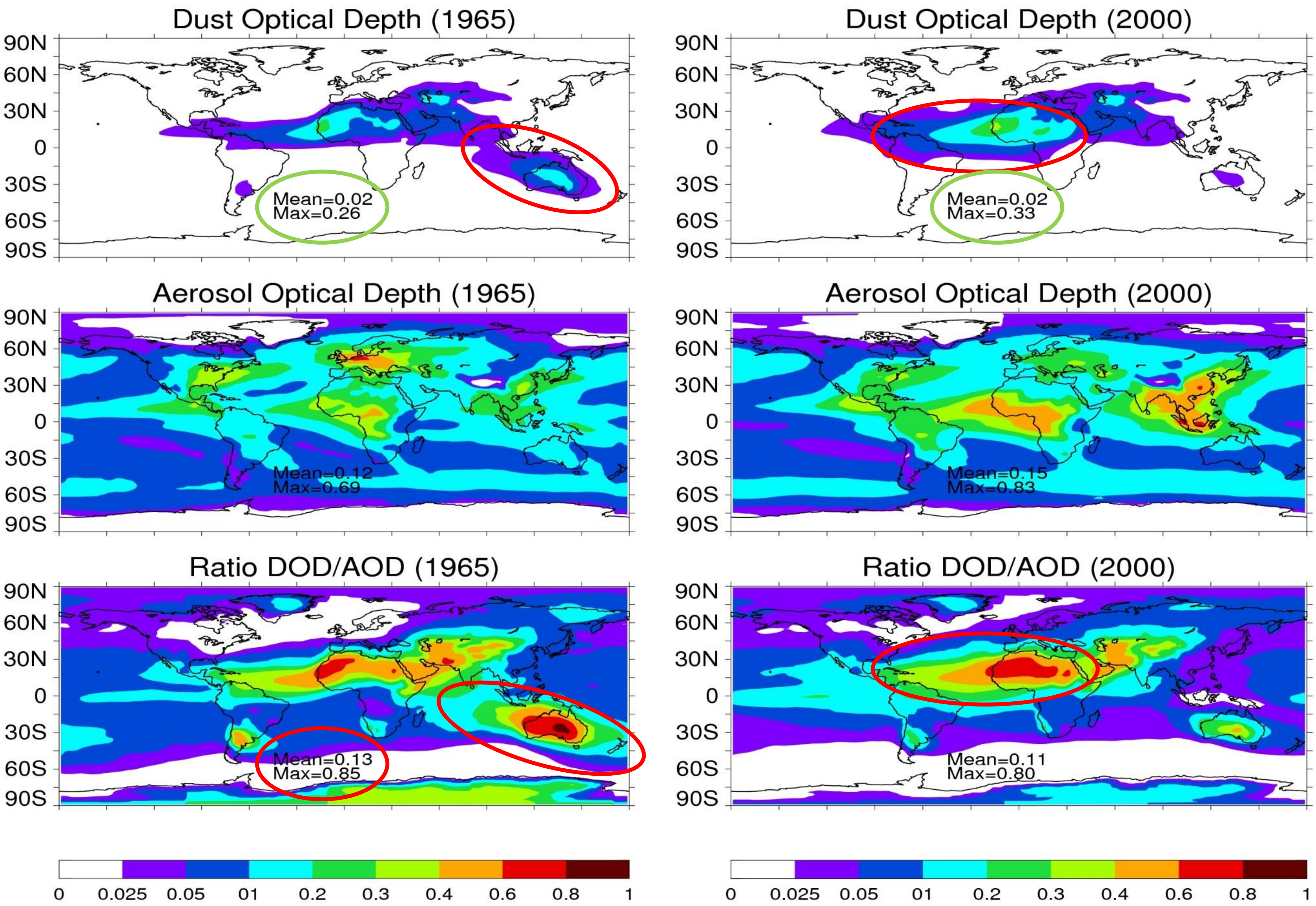
Global: only 10% change over 60 years.
Anthro dust ~25% (same as Ginoux et al., RoG, 2012)

Dust emission by regions (Tg/yr)

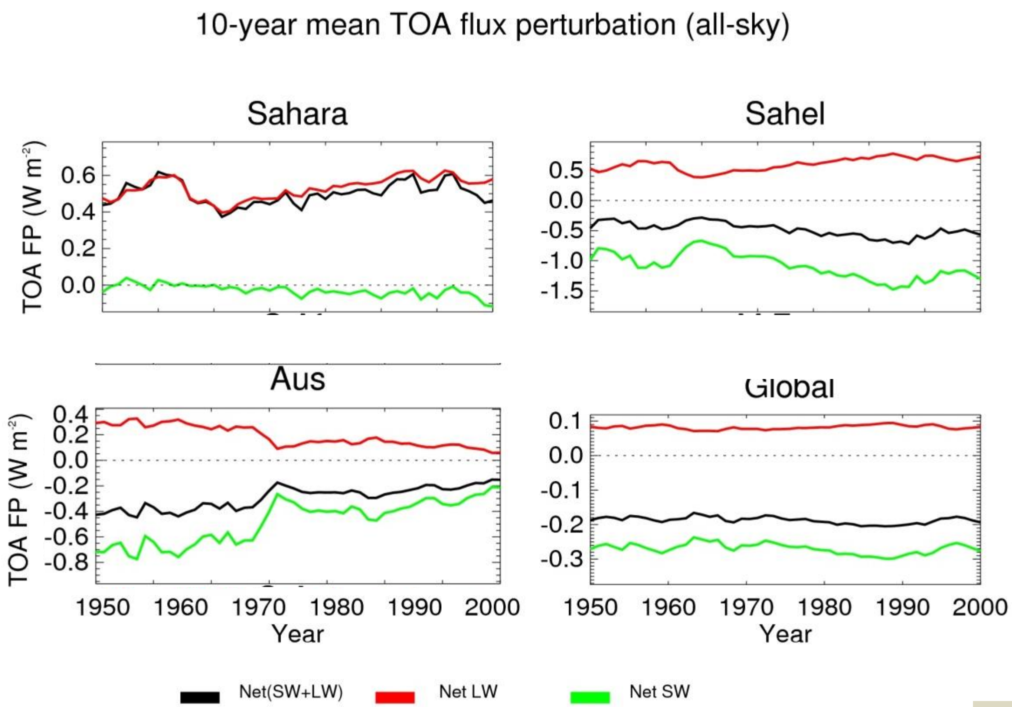




Aerosol Optical Depth



TOA Flux Perturbation (W/m^2)



LW+SW LW SW

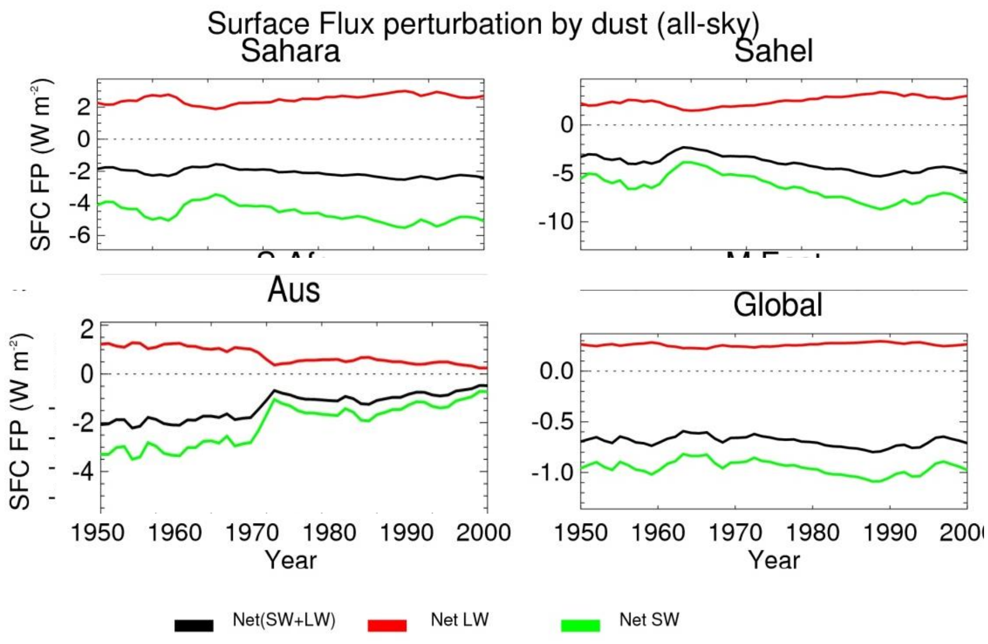
Sahara: highest warming due to LW absorption

Sahel: highest cooling due to scattering

Australia: 50% reduction of radiative cooling

Global mean RF TOA (All-sky) 2000:
Present study: **-0.22** W/m^2
Miller et al. (2004): -0.18 W/m^2
Miller et al. (2006): -0.4 W/m^2
Yoshika et al. (2007): -0.6 W/m^2
Takemura et al. (2009): -0.01 W/m^2

Surface Flux Perturbation (W/m^2)



LW+SW LW SW

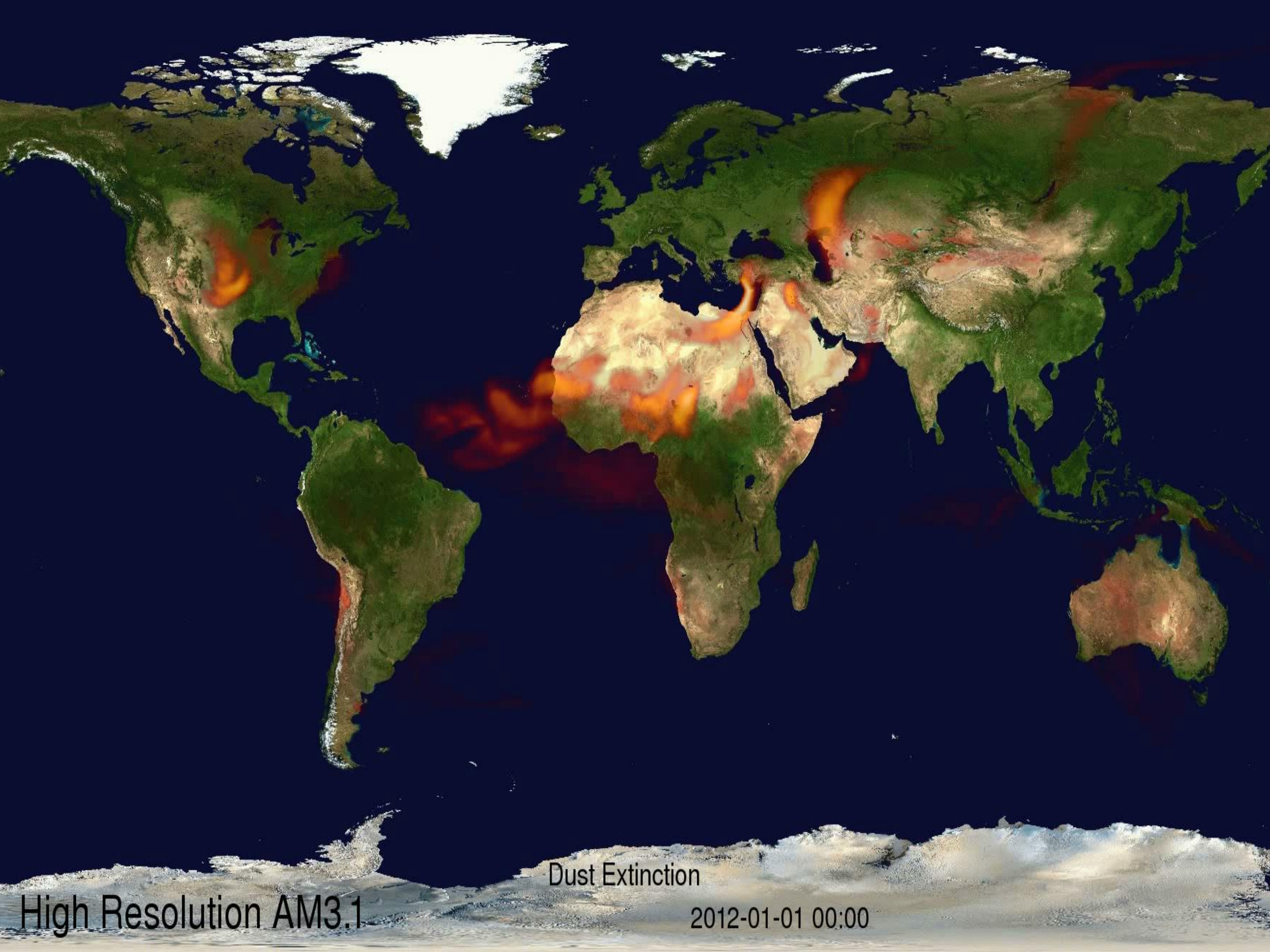
Australia SFP decreased from -2 to -0.5 W/m^2

Sahel highest SFP (-5W/m^2)

Global mean RF SFC (All-sky) 2000:
Present study: **-0.7** W/m^2
Miller et al. (2004): -1.64 W/m^2
Miller et al. (2006): -0.84 W/m^2
Yoshika et al. (2007): -0.46 W/m^2

Conclusions

- Implementing dust emission into the GFDL dynamic land model LM3 significantly improves dust decadal variation.
- Vegetation and landuse changes are the most important factors to explain dust decadal variability.
- Most significant changes: West Africa increase x2, and Australia decrease by x3, in agreement with observations.
- Globally, landuse accounts for 25% of dust emission, with large temporal and regional variations: Australia used to account for 50% but now reaches 90%, while in Sahara it accounts for 10%, in agreement with satellite based data (Ginoux et al., *Rev. Geophys*., 2012)
- The reversal of low dust from Africa and high dust over Australia has a canceling effect on decadal variation of global radiative forcing which stays around -0.22 W/m^2 at TOA and -0.7 W/m^2 at the surface.


Dust Extinction
High Resolution AM3.1
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