Anthropogenic dust experiment

Paul Ginoux (NOAA GFDL)

1. Motivation

Mineral dust affects climate by absorbing and scattering solar and terrestrial radiation as well as by modifying cloud properties [*Forster et al.*, 2007]. In addition, dust mediates carbon uptake by providing iron, a limiting nutrient in many ocean regions [*Jickells et al.*, 2005], and phosphorous to land surfaces (e.g., the Amazon forest [*Swap et al.*, 1992]). As one of the most abundant aerosols in the atmosphere, dust has also important implications regarding air quality [*Prospero*, 1999]. In order to estimate the impacts of dust on climate and air quality, we need to first identify and quantify the factors controlling dust. This has been the focus of numerous studies based on field campaigns, laboratory measurements, satellite data, and model simulations. Still, there are large uncertainties regarding the impact of land use changes on modulating dust emission directly, e.g., by disturbing soils, removing vegetation cover, or desiccating water bodies, and indirectly, by changing climate and the hydrological cycle. Most recent estimate of global contribution of land use to dust emission is around 25% (cf. Figure 1). Although such estimate is based on high-resolution satellite data, large uncertainty remains due to unconstrained threshold of wind erosion. This threshold is the minimum surface wind speed necessary to initiate dust emission. Its value depends on the surface characteristics, such as soil composition, soil moisture, and vegetation cover, which are treated differently between models. Ultimately, it will affect modeling dust lifecycle from emission to deposition.

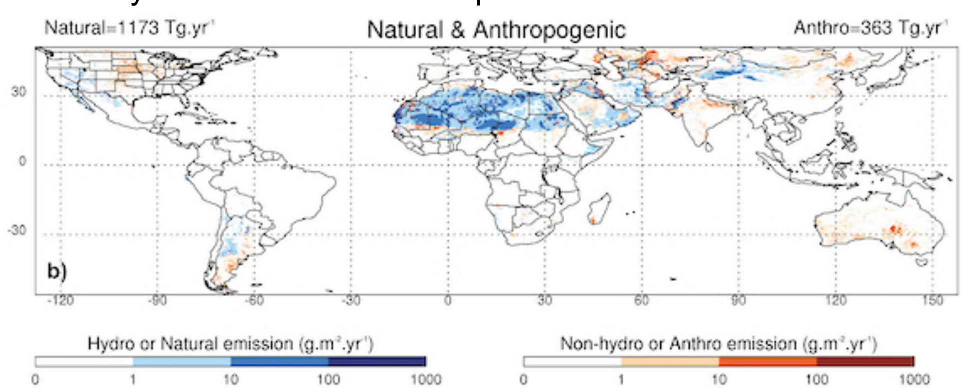

Figure 1. Dust emission from natural and land use [g/m2/yr] estimated from MODIS Deep Blue aerosol products, HYDE2 land use dataset, and high resolution GFDL-HIRAM atmospheric model (Ginoux et al., Rev. Geophys., 2012)

Experiments for dust models are proposed to estimate the contribution of land use to dust emission, deposition, and optical properties. In addition a sensitivity study related to the threshold of wind erosion is proposed. Multi-models comparison with observations will provide an envelope of uncertainties.

2. Science questions

– What is the contribution of land use to global and regional dust emission, deposition and optical properties? Is there contrast of such contributions between regions over land and oceans? What could be the potential impact on climate and earth's system assuming different mineralogical composition between natural and agricultural dust?

– What is the best-estimated value of velocity threshold of wind erosion (U_t) for land-use areas? Does future land use changes will affect dust emission from agriculture?

– What is the level uncertainty of anthropogenic dust emission/deposition and optical properties associated with numerical models?

3. Planned model experiments

The Anthro-dust experiment consists to run one control experiment (CTRL2016) with standard configuration for 3 years from 2010 to 2012, and perturbed cases with satellite based inventory (MDB2-A; MDB2-Ba…MDB2-Bc; MDB2-C), which differentiates between natural and land use dust sources.
To better constrain the threshold of wind erosion (Ut0) a sensitivity study is performed with Ut0 multiplied by 1 (MDB2-Ba), 0.5 (MDB2-Bb),1.5 (MDB2-Bc) and 1.25 (MDB2-Bd) for land use sources (the natural source is shutdown). Then both, natural and anthropogenic dust sources are activate using everywhere Ut0. But before performing the perturbed case, it is necessary to perform a simulation (MDB2-A) with provided natural sources (foo_nat). This experiment is used to determine the global constant of emission(C) such that the global annual dust emissions from the control (C0) and new inventory (Cnew) have the same value.
Simulation period: 3 years from 2010 to 2012

Name	Description
CTRL2016	Simulate with your own sources using your own C0 and Uto
MDB2-A	Simulate with MDB2 natural sources with Uto, then calculate global emission Cnew to have same global mean annual emission as in 1. Cnew=C0 * (global mean annual emis CTRL2016)/(global mean annual emis MDB2-A)
MDB2-Ba	Simulate with MDB2 anthropogenic sources with Cnew and Uto
MDB2-Bb	Simulate with MDB2 anthropogenic sources with Cnew and 0.5*Uto
MDB2-Bc	Simulate with MDB2 anthropogenic sources with Cnew and 1.5*Uto
MDB2-Bd	Simulate with MDB2 anthropogenic sources with Cnew and 1.25*Uto
MDB2-C	Simulate with MDB2 natural and anthropogenic sources with Cnew and Uto, respectively

4. Input dataset

- Annual Frequency of occurrence (FoO) that MODIS Deep Blue Level 2 C6 Dust Optical Depth (DOD) is greater than 0.2 average over 13 years (2003 to 2015). FoO is expressed in fraction per year with values from 0 to 1; and is used directly as fraction of dust source. The method is described in details by Ginoux et al. (Rev. Geophys., 2012).
- The natural and anthropogenic sources are separated using a value of 30% land use (cropland and pasture) as provided by HYDE-2 (Klein Goldewijk, 2001).
- Fields:
    - foo = total dust source fraction (foo_nat+foo_ant)
    - foo_nat = natural source fraction (landuse < 30%)
    - foo_ant = anthropogenic source fraction (landuse >= 30%)
- Valid values of foo: 0 to 1
- Units: none
- Resolution: annual 0.25^{o}x0.25^{o} and 1^{o}x1^{o}
- Format: netcdf

5. Diagnostics

Needed diagnostics are subset of Aerocom Phase-3 (AP3-CTRL) diagnostics

- Static:
    - Vertical coordinate system (ak, bk)
    - Altitude above sea level (orog)
    - Land/sea mask (sftlf)
    - Dust size distribution: for each bins or modes
        - Distribution function (e.g. lognormal, dM/dlnR=0, etc.),
        - Radius: Minimum, Maximum, Effective (m)
        - Density (kg/m^3)
- 2-D daily:
    - Surface: pressure (ps), temperature (ts), wind (sfcwind), max wind (sfcwindmax), relative humidity (hurs), specific humidity (huss)
    - Precipitation (pr)
    - Mean volumetric soil moisture (if used in dust emission)
    - Mean Leaf Area Index (if used in dust emission)
    - Aerosol: optical depth (aer550) absorption optical depth (abs550aer)
    - For each dust modes or size bins
        - Emission (emidust)
        - Deposition: dry (drydust) and wet (wetdust)
        - Dust mass mixing ration (mmrdust
        - Dust burden (loaddust)
        - Optical depth (od550dust), Absorption (ab550dust)
    - TOA radiative fluxes: rsdt, rsut, rsutcs, rsutcsaf, rlut, rlutcs, rlutcsaf
- 3-D daily:
    - For each dust size bins: Dust concentration (mmrdust)

6. Timetable

Submission deadline: June 2019
Analysis: completion for Aerocom 2019
Paper: 1st draft for Aerocom 2019; Submission by December 2019

References

Forster, P., et al. (2007), Changes in atmospheric constituents and in radiative forcing, in Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, edited by S. Solomon et al., pp. 129–234, Cambridge Univ. Press, Cambridge, U. K.

Ginoux, P., J. M. Prospero, T. E. Gill, N. C. Hsu, and M. Zhao (2012), Global‐scale attribution of anthropogenic and natural dust sources and their emission rates based on MODIS Deep Blue aerosol products, *Rev. Geophys.*, **50**, RG3005, doi:10.1029/2012RG000388.

Huneeus, N., et al. (2011), Global dust model intercomparison in AeroCom phase I, *Atmos. Chem. Phys.*, **11**, 7781–7816, doi:10.5194/acp‐11‐7781‐2011.

Jickells, T. D., et al. (2005), Global iron connections between desert dust, ocean biogeochemistry, and climate, *Science*, **308**, 67–71, doi:10.1126/science.1105959.

Klein Goldewijk, K. (2001), Estimating global land use change over the past 300 years: The HYDE database, *Global Biogeochem. Cycles,* 15, 417–433.

Prospero, J. M. (1999), Long‐term measurements of the transport of African mineral dust to the southeastern United States: Implications for regional air quality, *J. Geophys. Res.*, **104**(D13), 15,917–15,927.

Swap, R., M. Garstang, S. Greco, R. Talbot, and P. Kallberg (1992), Saharan dust in Amazon Basin, *Tellus, Ser. B*, **44**, 133–149.