Two-parameter approach for estimating biomass burning emissions of NO_x for the African continent

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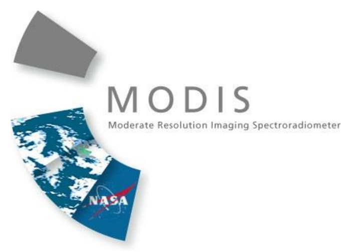
Motivation

Current fire emission inventories are based on at least three parameters and apply universal emission factors (EFs) for the calculation of NO_x emissions over large biomes such as savannas. However, recent satellite-based studies over tropical and subtropical regions have indicated spatio-temporal variations in EFs within specific biomes.

In this study, tropospheric NO_2 from OMI and fire radiative power from MODIS are used to estimate *fire emission rates (FERs) of NO_x* for different biomes of Africa. These monthly resolved *FERs* are applied together with *fire radiative energy (FRE)* as derived from SEVIRI to estimate total fire emissions of NO_x for the African continent.

Instruments and data retrieval

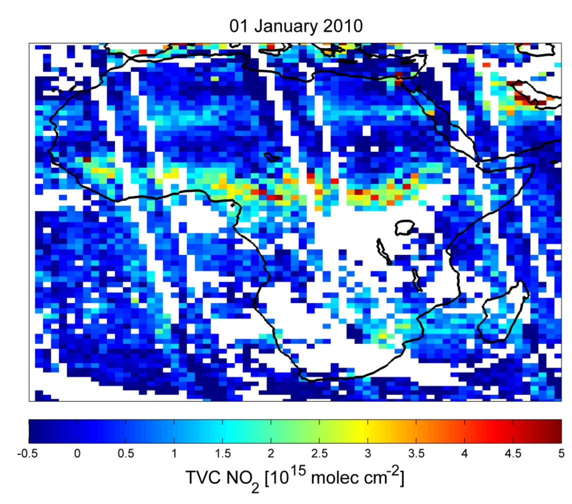
- OMI on board NASA's EOS-Aura
- spectral measurements (270-500 nm)
- OMI overpasses the equator in the ascending node at 13:30 LT
- pixel size is 13 x 24 km² at nadir
- OMI provides global coverage every day
- NO_2 slant columns downloaded from: http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI/omno2_v003.shtml



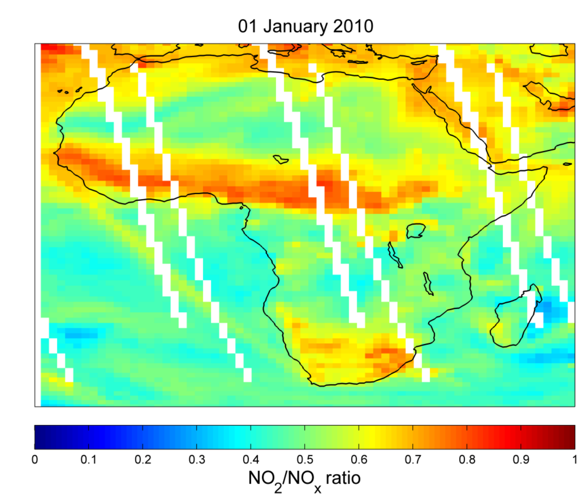
- MODIS on board NASA's Aqua
- 36 spectral bands (0.4-14.4 µm)
- equatorial overpass time at 13:30 LT
- differences in 4- and 11-µm black body radiation to derive active fires at 1 km²
- fire radiative power downloaded from: ftp://fuoco.geog.umd.edu/modis/C5/cmg/monthly/hdf/

- SEVIRI on board Meteosat second generation (geostationary orbit)
- 12 spectral channels in the visible and thermal infrared
- permanent visible and infrared imaging of the Earth's disc, with a baseline repeat cycle of 15 minutes
- fire radiative power provided by MACC

Tropospheric NO_2 and NO_2/NO_x ratio

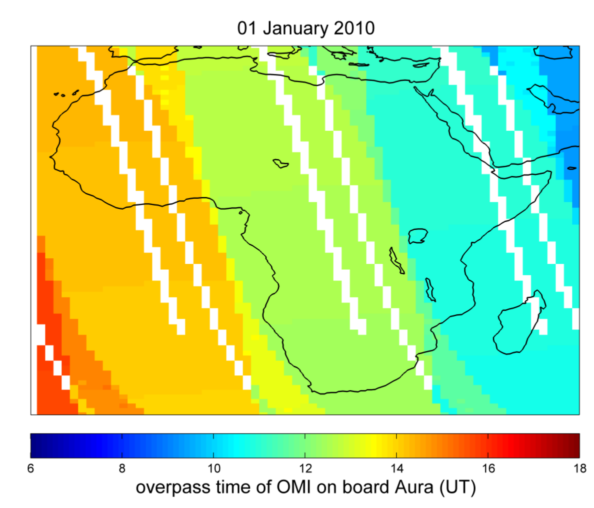


- MACC is a research project with the aim of establishing the core global and regional atmospheric environmental services for the European GMES (Global Monitoring for Environment and Security) initiative. (https://www.gmes-atmosphere.eu/)



Retrieval of tropospheric NO_2 vertical columns (TVC NO_2) from OMI data:

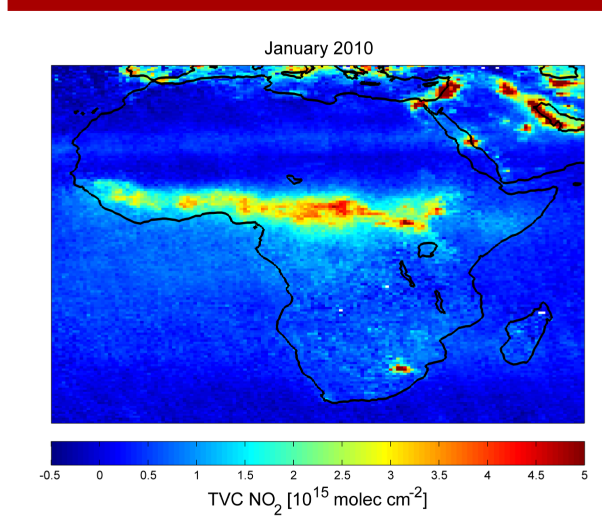
- the reference sector method is used for removing the stratospheric part from the NO_2 SCDs
- measurements with cloud fraction > 0.2 are removed via cloud screening by using the O_2-O_2 absorption band at 477 nm
- tropospheric SCDs are converted into TVC NO_2 by applying airmass factors as derived by SCIATRAN



Computation of NO_2/NO_x ratio:

- daily weighted averages of the NO_2/NO_x ratio are calculated for the 8 given UT hours (MACC reanalysis) by including 29 hybrid sigma-pressure levels between the surface and ~10 km altitude to reflect tropospheric values at a 1.125° x 1.125° grid
- interpolation to daily gridded maps of the geographical location of the OMI overpass time (UT) to construct daily values of the NO_2/NO_x ratio

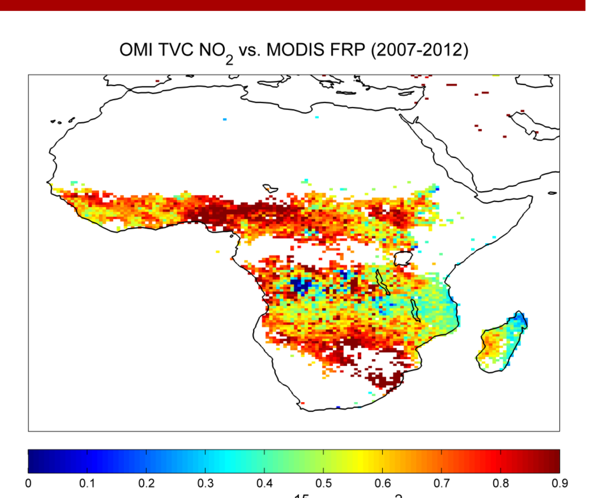
Production rates of NO_x from fire



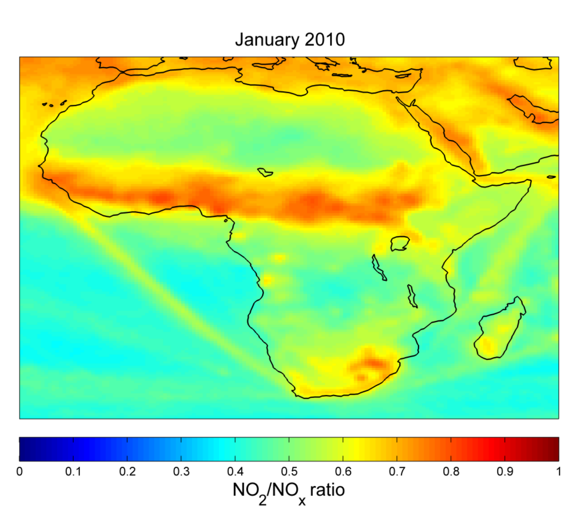
$$TVC[NO_2] = slope * FRP + TVC_b[NO_2]$$
(Eq. 1)

$$TVC_f[NO_2] = TVC[NO_2] - TVC_b[NO_2]$$
(Eq. 2)

$$P_f = \frac{TVC_f[NO_2] * M \left(1 + \frac{NO}{NO_2}\right) A_p}{N_A * \tau}$$
(Eq. 3)



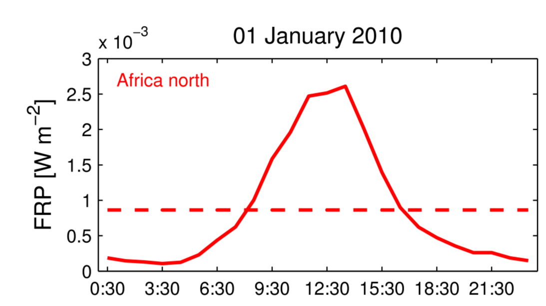
- monthly gridded means of TVC NO_2 are computed for the year 2010 at a horizontal resolution of 0.5° x 0.5°
- y-intercepts as derived from the linear relationship between TVC NO_2 and FRP (Eq. 1) are subtracted from the gridded TVC NO_2 values (Eq. 2)
- this step is performed to isolate the tropospheric NO_2 column contribution produced by fire (TVC$_f$ NO_2), assuming that y-intercepts represent the NO_2 background (TVC$_b$ NO_2)

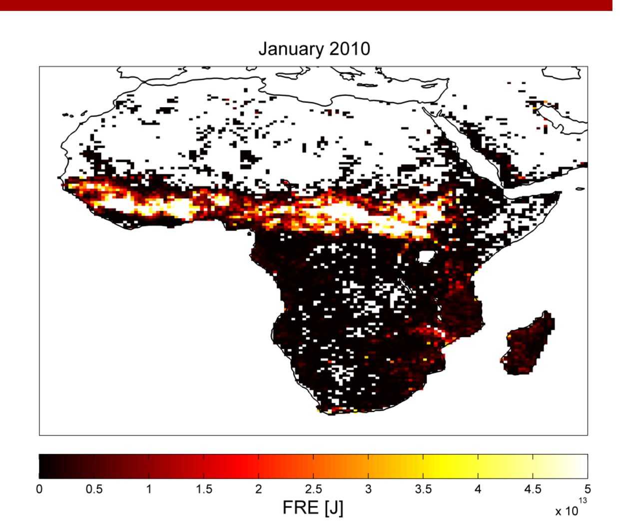


- the obtained monthly gridded values of TVC$_f$ NO_2 are converted into monthly gridded values of NO_x production rates P_f (in units of g NO_x s^{-1}) (Eq. 3)
- M is the molar mass of NO (in g mol^{-1})
- the term 1 + NO/NO_2 accounts for the NO_2/NO_x ratio (withouth units)
- A_p is the respective pixel area (in cm²)
- N_A denotes Avogadro's number (in molecules mol^{-1})
- τ is the assumed lifetime of NO_x (in seconds). Here, τ = 6 h

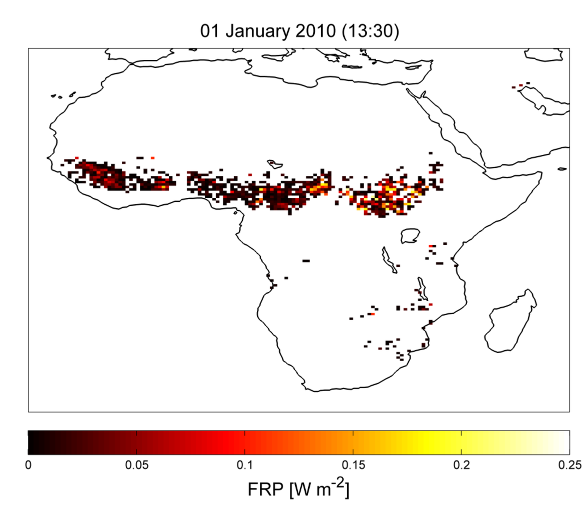
Fire radiative power (energy)

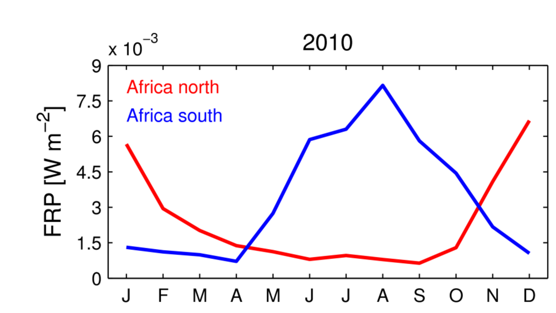
- FRP observations from SEVIRI on an hourly basis are used to determine the first parameter (*fire radiative energy*) of the presented approach to estimate fire emissions of NO_x for the African continent
- these hourly values are aggregated to daily mean FRP areal densities for all 0.5° x 0.5° grid cells
- there is a clear diurnal fire cycle with peak values in the afternoon





Africa north (AfN): 0° – 40°N, 20°W – 55°E
Africa south (AfS): 40°S – 0°, 20°W – 55°E

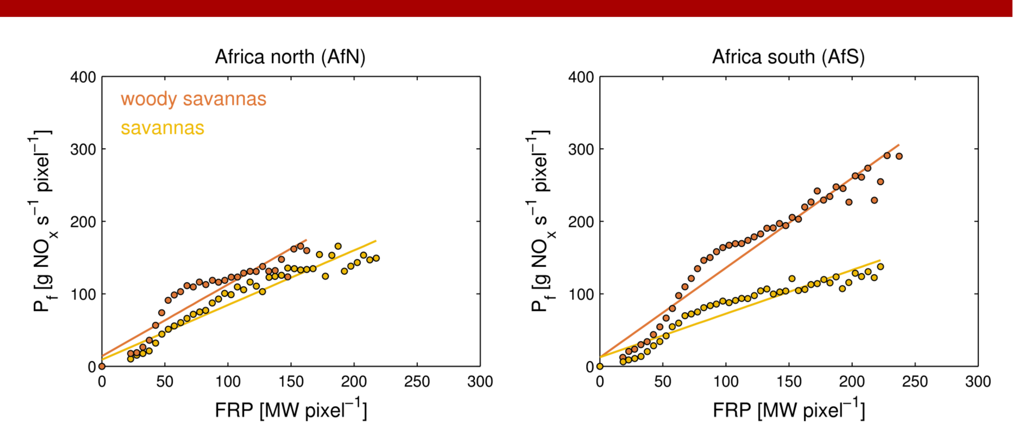




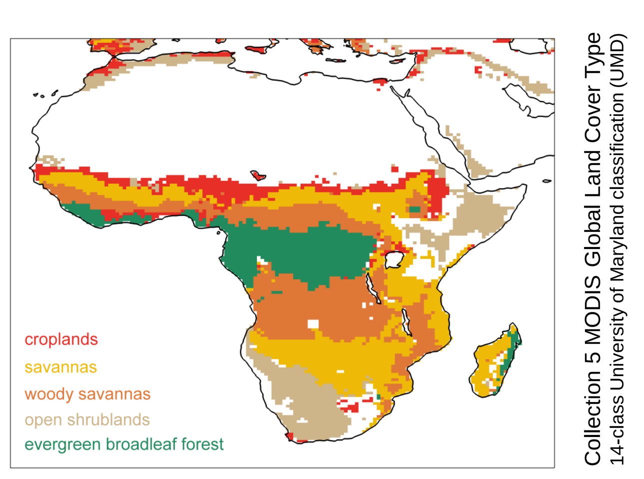
- besides the diurnal cycle, time series of monthly averaged FRP areal densities indicate a seasonal cycle, with peak values in December (Africa north) and August (Africa south)
- the daily mean FRP areal densities are then multiplied by the area of the respective grid cells
- finally, the FRP fields are temporally integrated to yield gridded monthly *fire radiative energy (FRE)* data

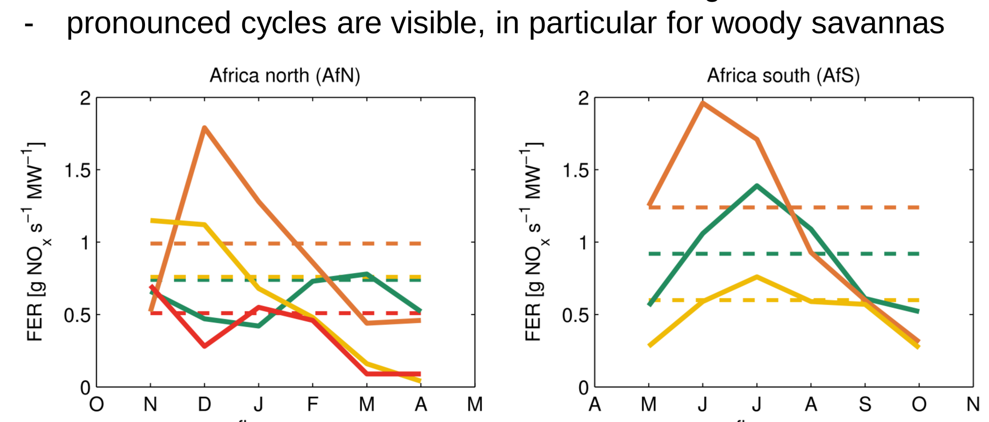
Fire emission rates of NO_x

- the second parameter (*fire emission rates of NO_x*) is based on the strong empirical relationship between P_f and FRP
- in this case, monthly means of FRP from MODIS on board Aqua (2007-2012) are applied
- seasonal averaged *FERs of NO_x* (best fitting least-squares regression lines) are estimated for the different land cover types burned in Africa
- recently, satellite-based studies have shown that fire emission rates can undergo significant spatial and temporal changes within a region and a fire season, respectively

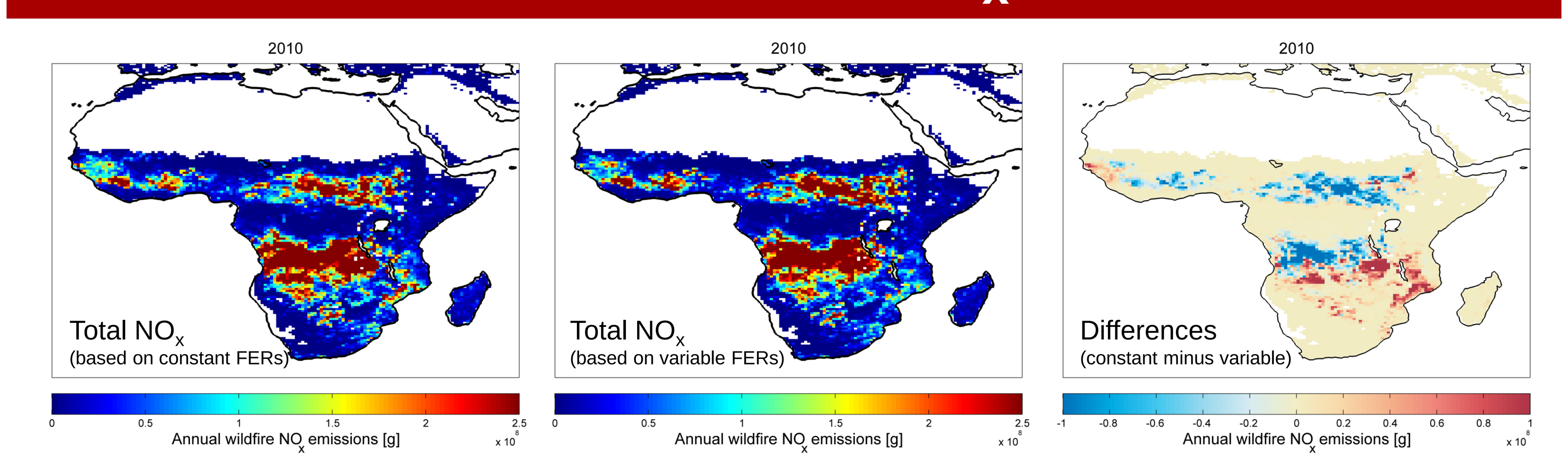


- therefore, monthly resolved *FERs of NO_x* are computed for the given land cover types and the two selected African regions
- there are clear differences between the two regions
- pronounced cycles are visible, in particular for woody savannas

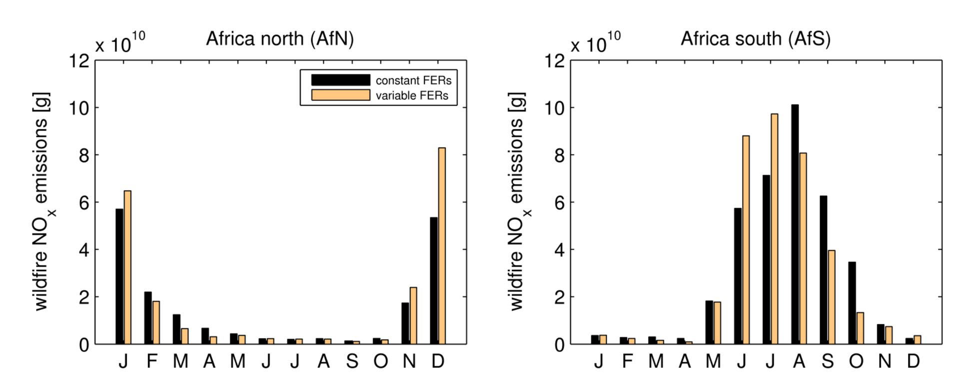


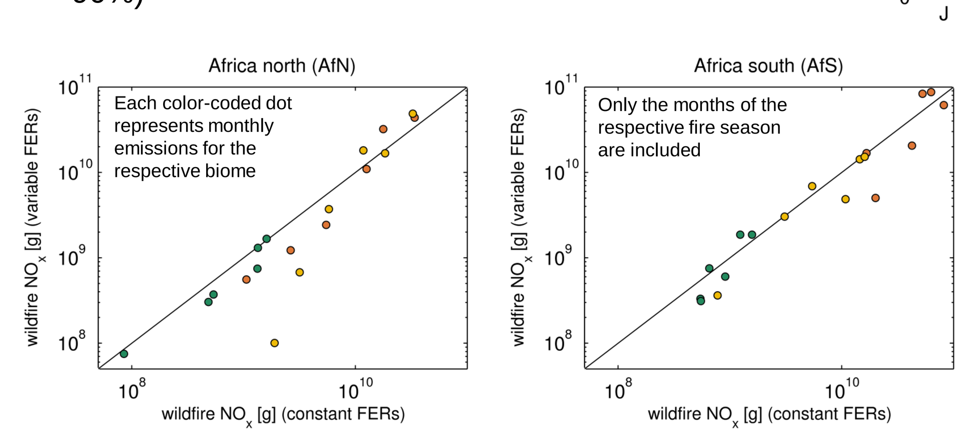


Total fire emissions of NO_x in Africa



- NO_x emissions for the two African regions are calculated from the product of *fire radiative energy* and *fire emission rates of NO_x*
- seasonally averaged (constant) and monthly resolved (variable) *FERs of NO_x* are applied
- there are differences between the two estimation approaches, in particular on a monthly basis (up to 90%)





- calculations based on the variable *FERs of NO_x* yield a (preliminary) total amount of 0.568 x 10^{12} g NO_x for the African continent in the year 2010
- when compared with averaged annual emissions of NO_x reported in recent bottom-up fire emission inventories, value estimated in this study is about eight times smaller

Summary & Conclusions

- A two-parameter approach for estimating wildfire emissions of NO_x in Africa is presented
- In comparison to recent bottom-up emission inventories
  - burned area, fuel load, and combustion completeness are substituted by *fire radiative energy (FRE)*
  - emission factors and associated conversion factors are substituted by *fire emission rates of NO_x (FERs)*
- The conversion of tropospheric NO_2 vertical columns from the OMI instrument into production rates of NO_x from fire (P_f) is based on monthly means of the tropospheric NO_2/NO_x ratio as derived from model data from MACC
- Fire radiative power from SEVIRI is temporally integrated to yield monthly gridded values of *FRE*
- The best fitting least-squares regression lines as derived from the linear relationship between P_f and FRP from MODIS are used to determine *FERs of NO_x* for different biomes
- Seasonally averaged (constant) and monthly resolved (variable) *FERs of NO_x* are applied together with *FRE* to estimate fire emissions of NO_x for the African continent
- Preliminary results show that differences between the two (constant vs. variable FERs) estimation approaches are up to 90% on a monthly basis

References & Acknowledgements

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