Using satellite measurements of tropospheric NO_2 and fire radiative power to derive biome-specific fire emission rates of NO_x

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Motivation

Biomass burning is a major source of nitrogen oxides (NO_x = NO + NO_2)

NO_x radicals play key roles in atmospheric chemistry, air pollution, and climate

How to measure?

NO_2 amounts and distributions are retrieved by passive and active remote sensing techniques

Aim of this study

To establish an empirical relationship bewteen **FRP** and **TVC NO_2** as a tool to estimate fire emissions of NO_x

How to estimate globally?

bottom-up approach
aggregate divers local statistics

top-down approach
inversion and partitioning of satellite-derived tropospheric NO_2

Satellite instruments and Data retrieval

Global Ozone Monitoring Experiment-2
- on board MetOp-A (EUMETSAT) since October 2006
- local equatorial crossing time: 9:30 a.m.

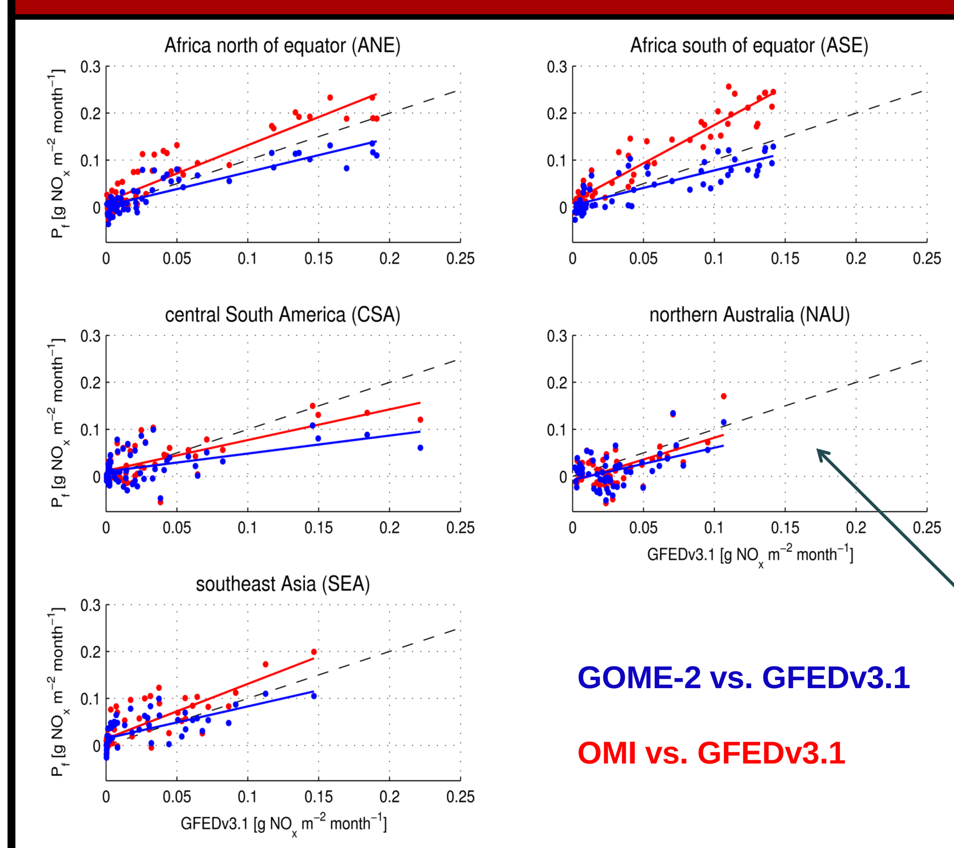
Ozone Monitoring Instrument
- on board EOS-Aura (NASA) since July 2004
- local equatorial crossing time: 1:30 p.m.

Differential Optical Absorption Spectroscopy (DOAS) to retrieve the Slant Column Densities (SCDs)
fitting window: 425-497 nm (GOME-2) and 405-465 nm (OMI)
reference sector method, cloud screening (FRESCO+), AMFs –> Tropospheric Vertical NO_2 Columns (**TVC NO_2**)

monthly means (2007-2011)

MODerate resolution Imaging Spectroradiometer
- on board Terra (10:30 a.m.) and Aqua (1:30 p.m.) satellites (NASA)
- MODIS fire products include the radiant component of energy release, the Fire Radiative Power (**FRP**)

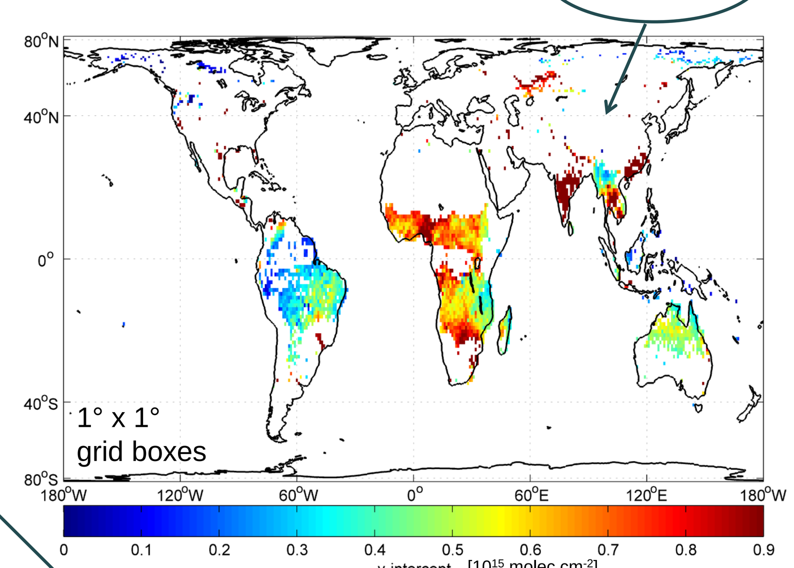
Conversion of TVC NO_2 into production rates of NO_x



GOME-2 vs. GFEDv3.1

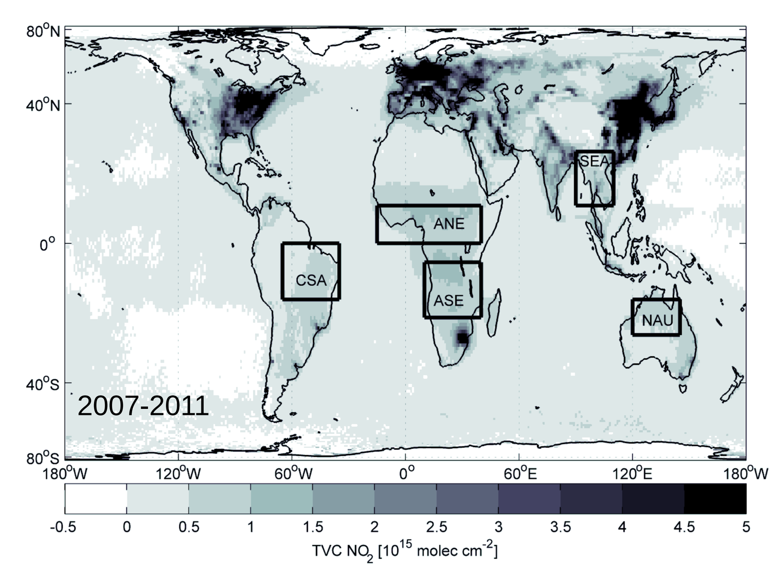
OMI vs. GFEDv3.1

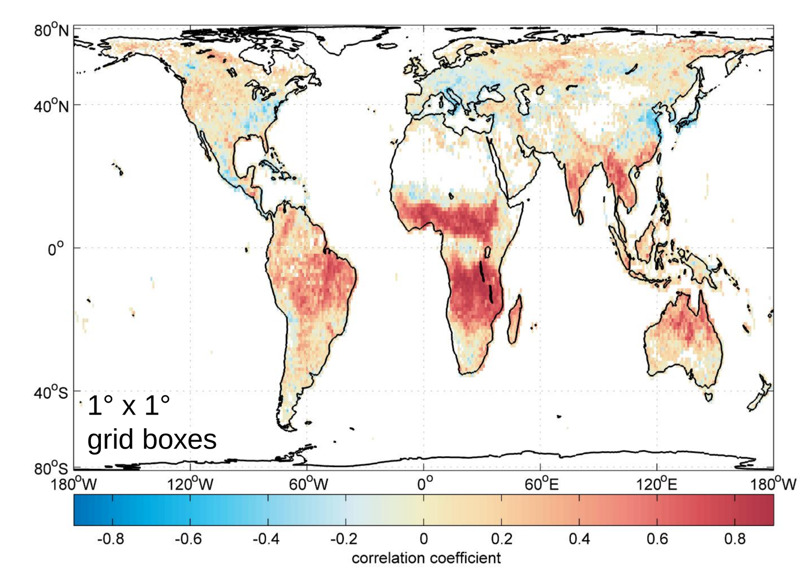
$$TVC_f[NO_2] = TVC[NO_2] - TVC_b[NO_2]$$



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

Relationship between TVC NO_2 and FRP

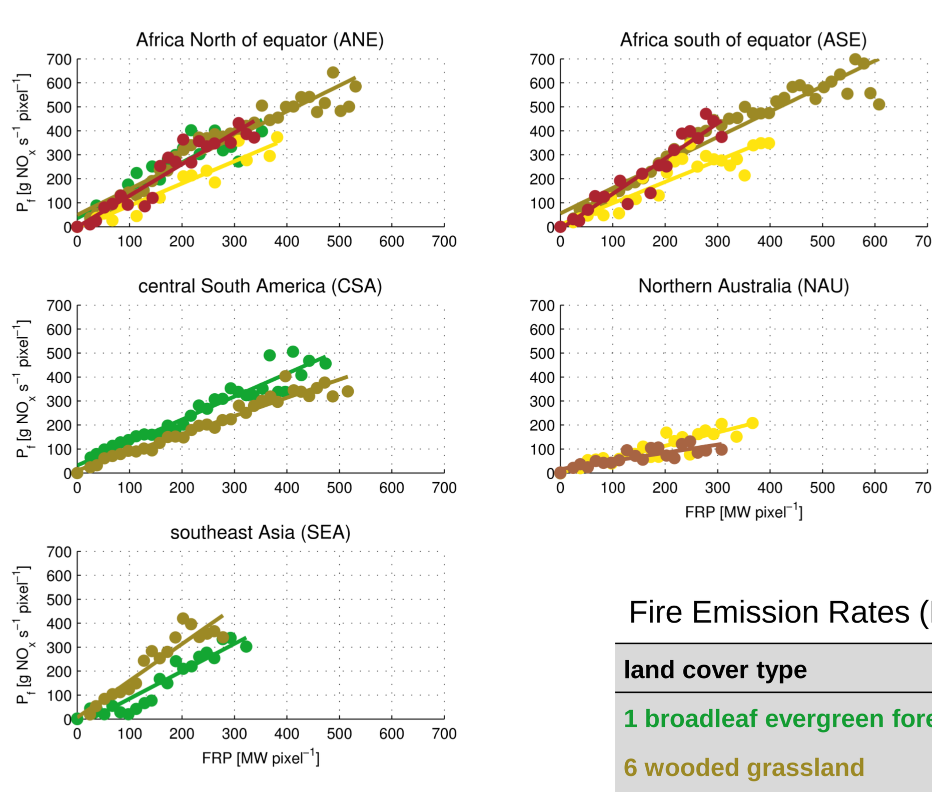


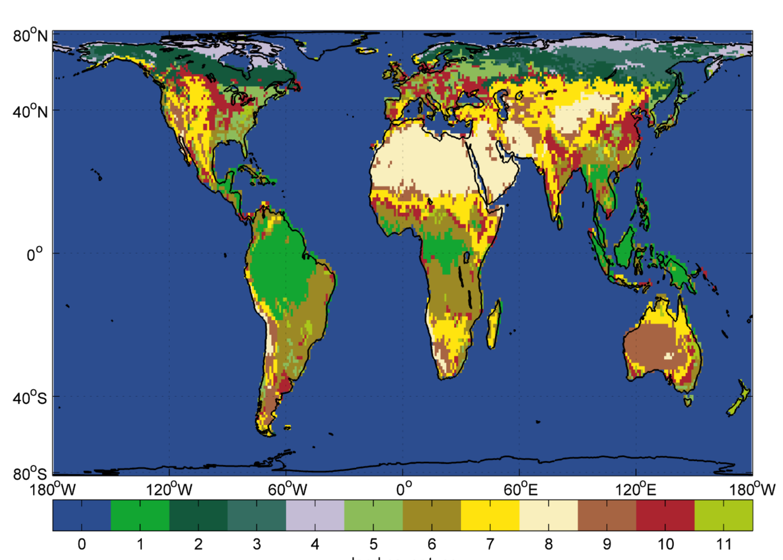


The emissions of NO_x from vegetation fires are much lower than anthropogenic emissions on the global scale. However, biomass burning is the major source of NO_x in large tropical and subtropical regions.

In these regions, the seasonal variation of fire intensity, expressed by the FRP data, is similar to the pattern of the column number density of NO_2 molecules, expressed by the TVC NO_2 data.

Results I – Biome-specific FERs





Fire Emission Rates (FERs) of NO_x in [g NO_x s^{-1} MW^{-1}]

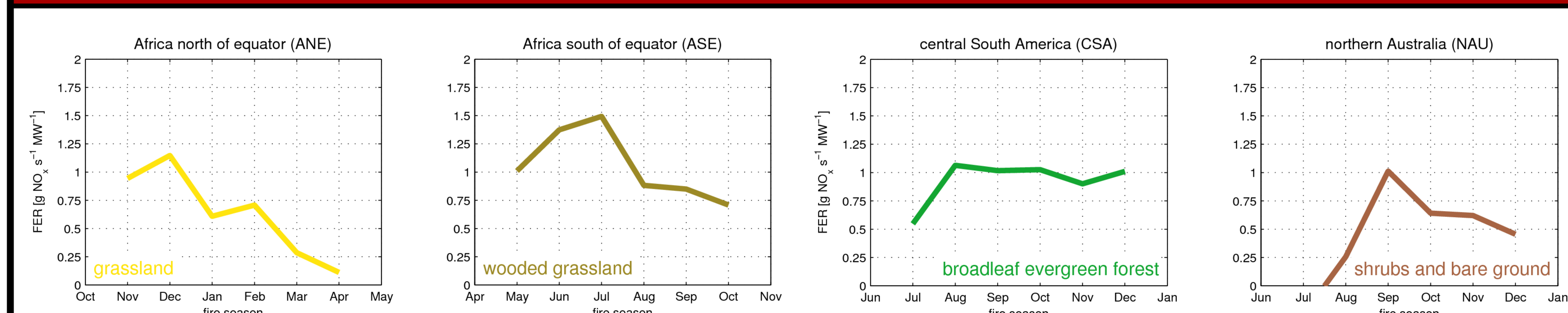
land cover type	ANE	ASE	CSA	NAU	SEA
1 broadleaf evergreen forest	1.41 / 1.25	-	0.91 / 0.75	-	1.19 / 1.10
6 wooded grassland	1.01 / 1.80	1.13 / 1.99	0.73 / 0.74	-	1.34 / 1.64
7 grassland	0.77 / 0.89	0.98 / 1.18	-	0.60 / 0.57	-
9 shrubs and bare ground	-	-	-	0.41 / 0.51	-
10 cultivated crops	1.25 / 1.99	1.43 / 1.77	-	-	

GOME-2 vs. MODIS Terra / OMI vs. MODIS Aqua

binning procedure

- FRP-interval 15 MW $pixel^{-1}$
- only if the number of values ≥ 25

Results II – Seasonal variability of FERs



possible explanations:

- seasonal variations in plant (leaf) percent N
- less N content at the end of the fire season
- seasonal variations in fuel moisture
- rainfall events during dry season enhance N

binning procedure

- FRP-interval 20 MW $pixel^{-1}$
- only if the number of values ≥ 2

monthly FERs of NO_x in [g NO_x s^{-1} MW^{-1}]

	ANE			ASE		CSA		NAU	
	1	6	7	6	7	1	6	7	9
JAN	1.43	1.30	0.61	-	-	-	-	-	-
FEB	1.14	1.02	0.71	-	-	-	-	-	-
MAR	0.48	0.21	0.29	-	-	-	-	-	-
APR	0.88	0.33	0.11	-	-	-	-	-	-
MAY	-	-	-	1.01	0.44	-	-	-	-
JUN	-	-	-	1.37	0.28	-	-	-	-
JUL	-	-	-	1.49	0.51	0.55	0.58	0.03	-0.26
AUG	-	-	-	0.88	0.64	1.06	0.52	0.42	0.26
SEP	-	-	-	0.85	0.74	1.02	0.71	0.75	1.01
OCT	-	-	-	0.71	0.74	1.03	0.74	0.70	0.64
NOV	1.46	0.48	0.94	-	-	0.90	0.68	0.52	0.62
DEC	1.92	0.61	1.15	-	-	1.01	0.84	0.72	0.46

GOME-2 vs. MODIS Terra

Conclusions and Outlook

- a simple statistical approach has been developed to estimate NO_x emission rates using the strong correlation between TVC NO_2 and FRP
- conversion of the TVC NO_2 into mass concentrations of NO_x by assuming constant NO_2/NO ratio and lifetime of NO_x –> very good agreement with GFEDv3.1 NO_x
- biome-specific FERs, but also differences among the selected regions
- seasonal variability of FERs – decreasing towards the end of the dry (fire) season
- future work will focus on other regions (e.g. boreal regions)

Acknowledgements

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MODIS data have been retrieved from: ftp://neespi.gsfc.nasa.gov/data/s4pa/Fire/
global land cover classification was provided by: http://glcf.umd.edu/data/landcover/
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