climate change initiative

→ FIRE

esa

Uncertainties in estimating biomass burning emissions for Africa: implications for atmospheric modelling

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Motivation

Fire emission inventories for Africa still differ largely.
The fire emissions uncertainty is a major constraint for accurately characterizing the impact of fires in Africa on air quality and climate.

The inventories rely on different satellite products of burned area (BA), hotspot (HS) or fire radiative power (FRP). Also, assumptions on the type of vegetation burned, fuel consumption and emission factors vary.

The recently released a 20-m Sentinel-2 BA product FireSFD11 can resolve the hitherto omitted smaller fires. In Africa, it detects 80% more BA than the most widely used MODIS BA product, and the implications of this increase on fire emissions warrant further analysis.

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Objectives

- create a fire emissions inventory for Africa for 2016 from the FireCCISFD11 and the 250m MODIS FireCCI51 BA product
- inter-compare different fire emission inventories for Africa
- identify sources of discrepancies
- perform WRF-Chem atmospheric chemistry model simulations using the inventories as boundary condition.
- compare modeled trace species concentrations with atmospheric observations to obtain a top-down constraint on fire emissions
- provide scientific basis for policy makers in air pollution control

Estimation of fire emissions

emission = burned area x fuel consumption x emission factor

Parameterisation with field measurement databases
- fuel consumption (FC) (van Leeuwen *et al.*, 2014)
- emission factor (EF) (Andreae, 2019)

by fire type classes

class decription	fuel consumption (FC) (tons ha^{-1})						emission factor (EF) (g kg^{-1})					
	global			Africa			CO		NO_x (as NO)		$PM_{2.5}$	
	M	(SD)	*N*	M	(SD)	*N*	M	(SD)	M	(SD)	M	(SD)
tropical forest	126	(77)	*22*	n.d.			104	(39)	2.8	(1.3)	8.3	(3.3)
wooded savanna	5.1	(2.2)	*9*	3.9	(1.2)	*3*	69	(20)	2.5	(1.3)	6.7	(3.3)
grassland savanna	4.3	(2.2)	*13*	3.2	(0.8)	*5*						
crop residue	6.5	(9)	*4*	n.d.			76	(55)	2.4	(1.2)	8.2	(4.4)

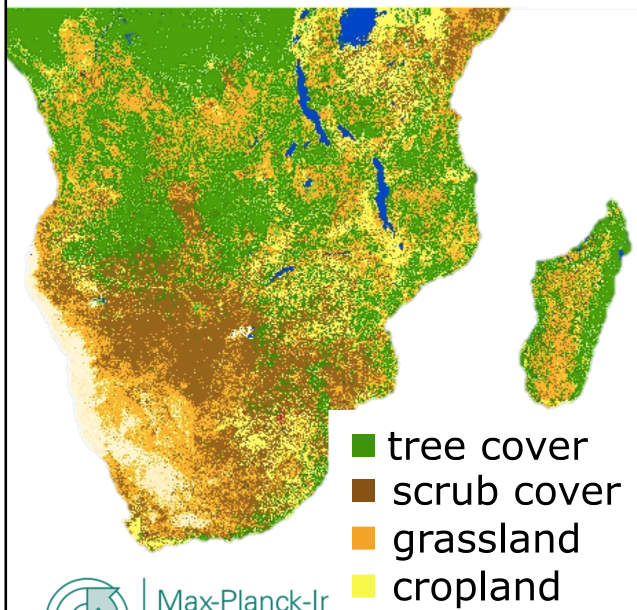
CO emission per m^2:
tropical forest=
37*wooded savanna

- fire type class strongly influences emissions
- only few FC data for Africa, interannual FC variability unrepresented
- unclear how to translate fire type classes to land cover maps

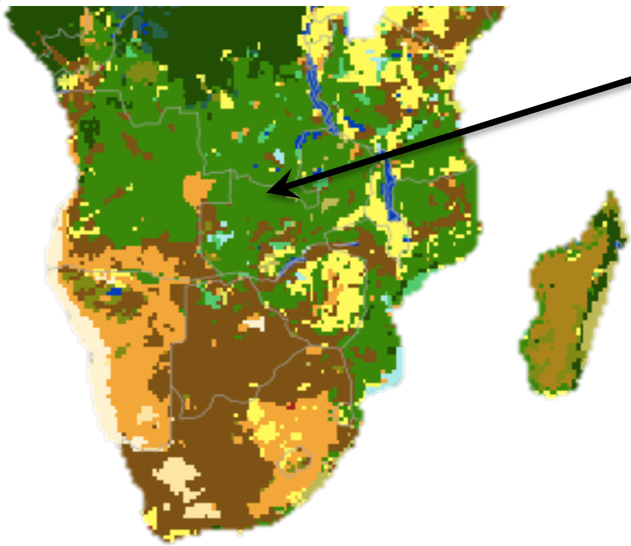
Estimation of fire emissions

How to assign vegetation information in FireCCI BA products to fire type classes?

SDF11:
S2 prototype 20m land cover
with 10 generic classes



CCI51:
LC_cci v2.0.7 land cover
with 22 UN-LCCS classes



#	Class
10	CRORAIN
20	CROIRRI
30	CROMOS
40	NATVEG
50	TREEEB
60	TREEDB
70	TREEEN
80	TREEDN
90	TREEMIX
100	TREEMOS
110	HERBMOS
120	SHRUB
130	GRASS
140	MOSS
150	SPARSE
160	TREEWATF
170	TREEWATS
180	HERBWAT
190	URBAN
200	BARE

class 60= "Tree cover, broadleaved, deciduous, closed to open (>15%)" <u>represents woody savanna</u> (Bai 2010)

savanna & forest is represented as tree cover in SFD11

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Estimation of fire emissions

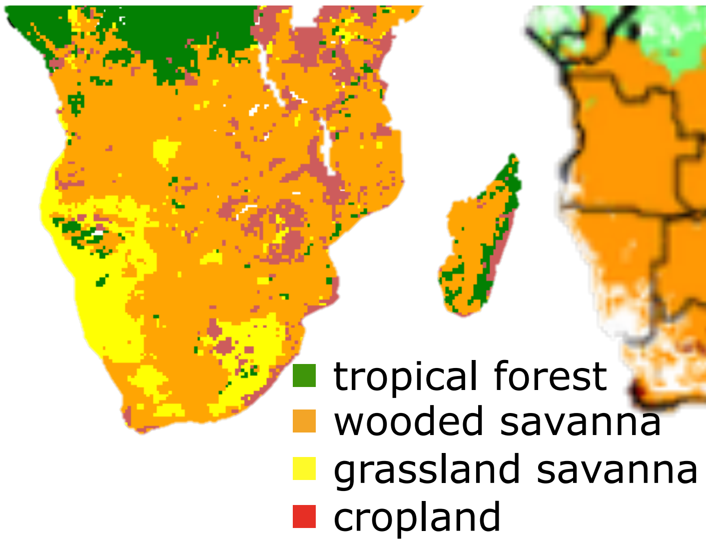
Translation scheme to 4 generic fire type classes

ID	fire type	LC_cci v2.0.7 UN-LCCS	ESA CCI S2
TROFOR	tropical forest	50,70,80,90,100,160,170	tree cover
WOODSAV	wooded savanna	60,110,120,180	shrub cover
GRASSAV	grassland savanna	130,140,150	grassland
CROP	crop residue	10,20,30,40	cropland

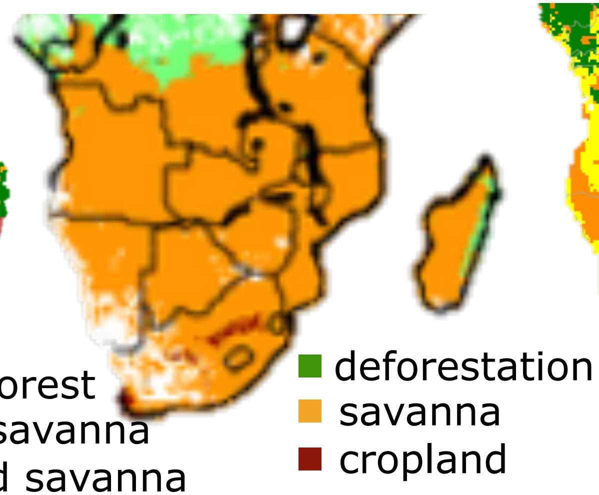
Derive fire type map from LC_cci

similar delineation between
tropical forest & savanna
as in e.g. GFED4 and FINN
fire emission inventory

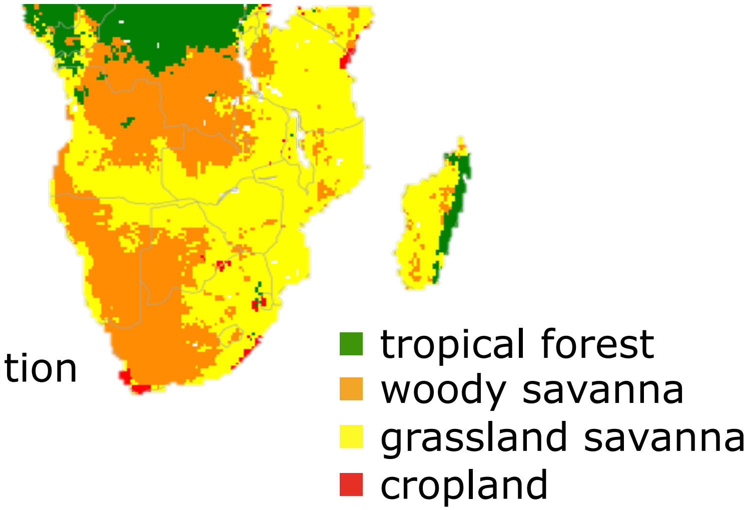
LC_cci



GFED4(s)



FINN



Estimation of fire emissions

Estimated fire CO emissions (Tg) Africa JAS 2016

static FC (van Leeuwen database) ← → dynamic FC (modelled by GFED4s)

fire type	CCI51	SFD11	SDF11-LC
TROFOR	49	823	78
WOODSAV	30	8	47
GRASSAV	2	18	3
CROP	4	7	6
Total	**86**	**855**	**133**

SFD11 emissions are 894% higher as in CCI51 while SFD11 burned area is only 54% higher

fire type	CCI51	SFD11	SDF11-LC
TROFOR	5	61	10
WOODSAV	49	10	77
GRASSAV	3	34	3
CROP	6	8	6
Total	**62**	**113**	**96**

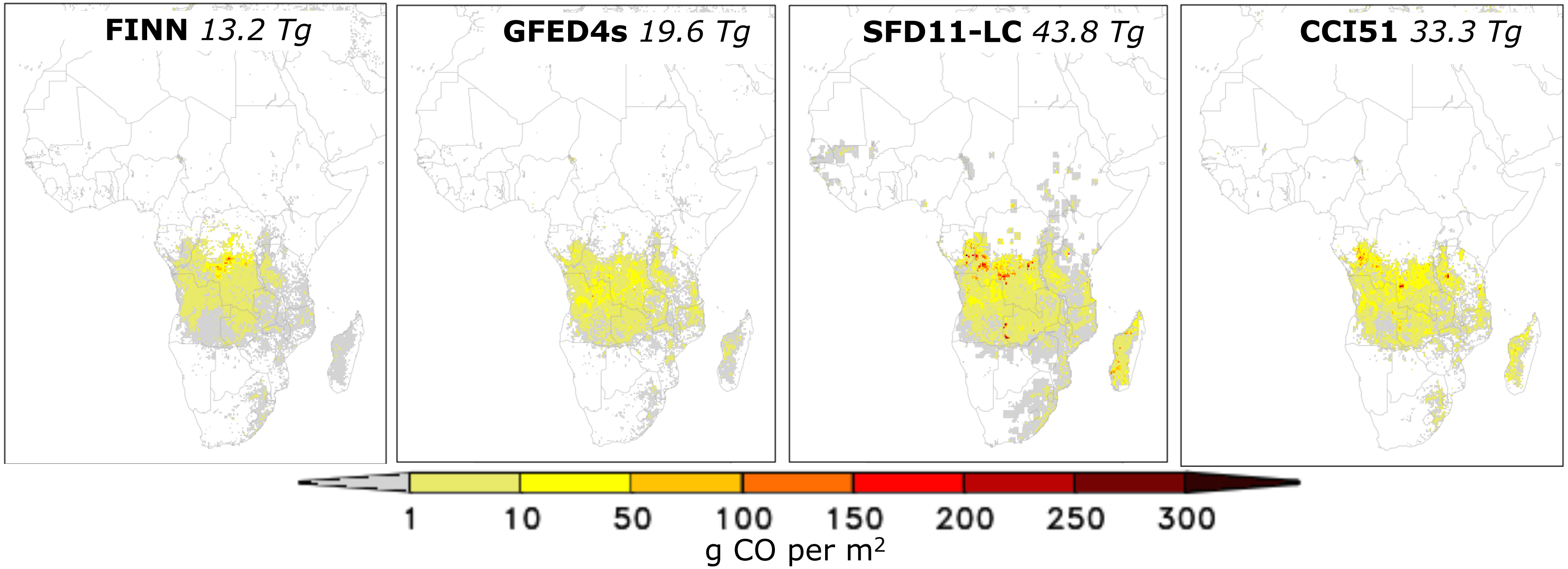
SFD11-LC: using LC_cci land cover

- GFED4s FC in the regions mapped as TROFOR is significantly lower than in the static FC approach (GFED field mean: 10.5 t ha^{-1} vs. 126 t ha^{-1})
- GFED4s FC for the other fire types is on average 40 - 80% higher
- Using GFED4s FC yields 28% lower CO emissions than in CCI51 and SFD11-LC

Estimation of fire emissions

Estimated CO fire emissions in July 2016

0.25d gridded maps, FireCCI emissions parameterised with static FC



GFED4s and FireCCI-derived emissions are substantially higher than FINN.

WRF-Chem Forecasting System
(DKRZ, Hamburg, Germany)

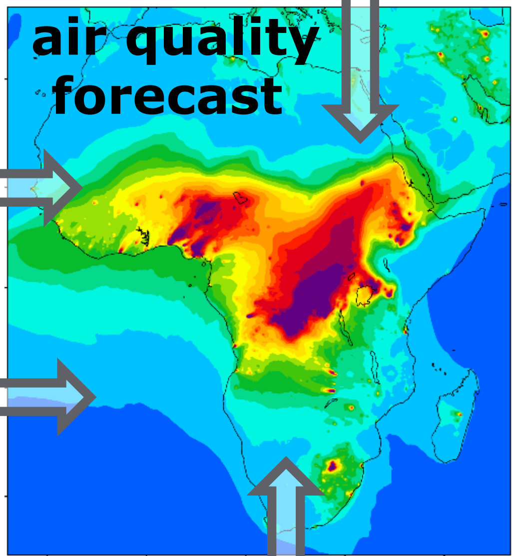
global NCEP atmospheric reanalysis

meteorology forecasts

WRF meteorology spinup

chemical boundary conditions: ECMWF-CAMS

chemical initial conditions: day-1 forecast



surface emissions

setup of WRF-Chem (v4.1.2) with

- MOZART-4 gas-phase chemistry
- GOCART bulk aerosol chemistry
- anthropogenic emissions: CAMS-GLOB-ANTv41 + diurnal cycle
- biogenic emissions: MEGAN online
- fire emissions: reference run FINN with online plume rise module
- domain: entire African continent
- spatial resolution: ~25 km
- study period: JUL-SEP 2016

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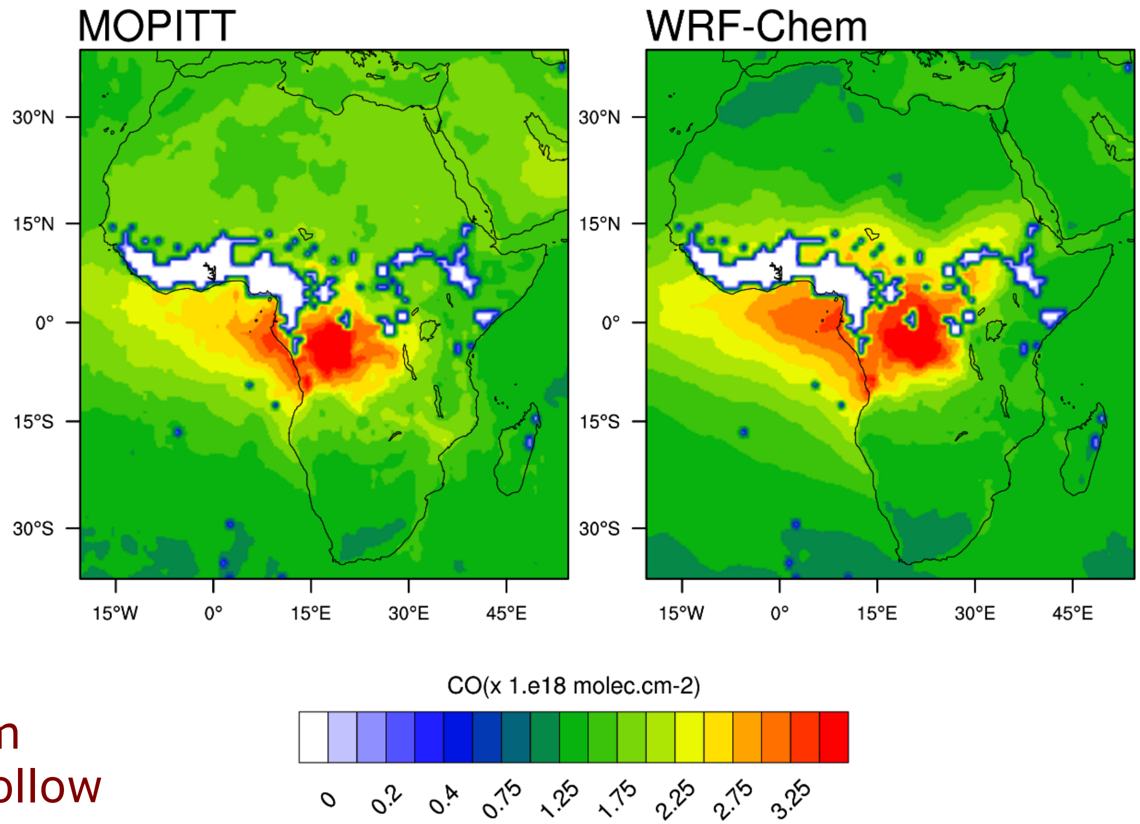
WRF reference simulation with FINN

- CO total columns observed by MOPITT satellite and simulated by WRF-Chem for July 2016 (FINN fire emissions)
- Spatial patterns of biomass burning-induced CO well captured by the model
- Slight overestimation of CO by the model in Gulf of Guina



Simulations with fire emissions from FireCCI products and GFED4s will follow

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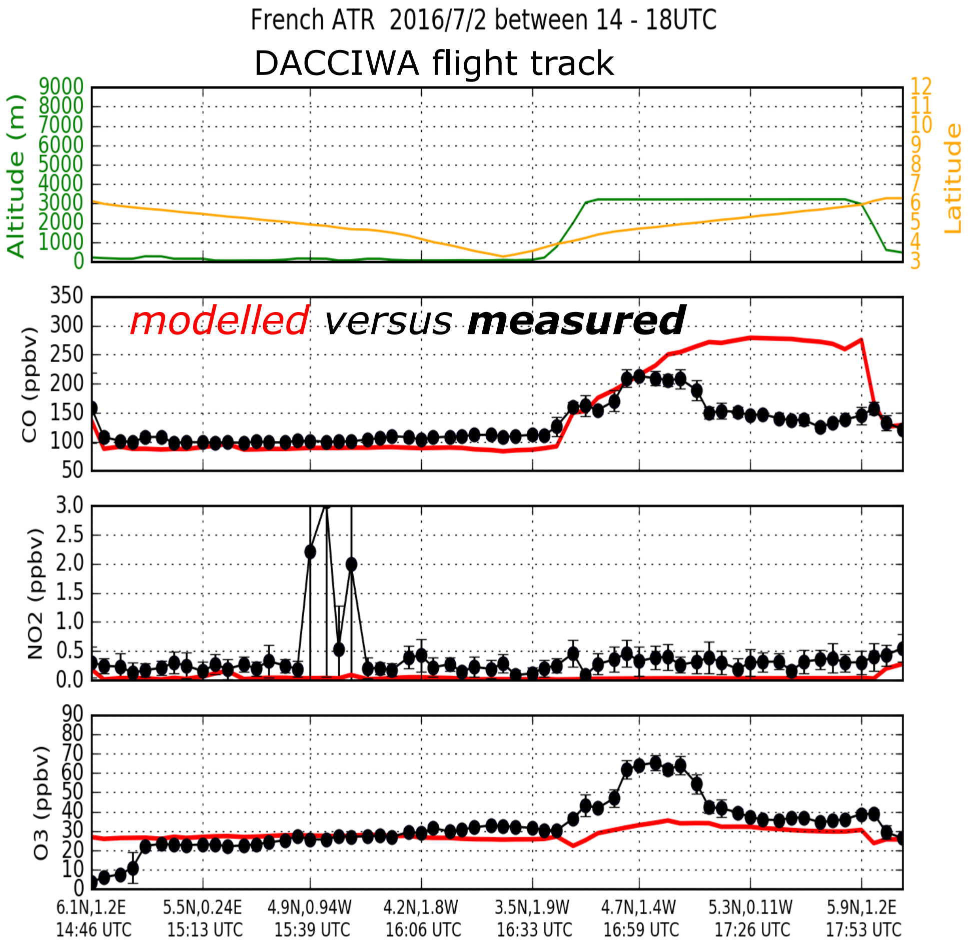
WRF reference simulation with FINN



- Evaluation of modelled concentrations with DACCIWA aircraft measurements (Flammant et al. (2019))
- WRF-Chem FINN captures CO biomass burning plume on July 2pm, but overestimates the concentrations
- CO overestimation consistent with MOPITT (see previous slide)
- O_3 is underestimated, probably due to the underestimation of NO_2
  → needs further investigation

Conclusions & Outlook

- Large uncertainties in fire emissions estimates due to unclear mapping: what is parameterized as savanna, what as forest fires?
- Land cover information provided with new FireCCISFD11 suboptimal for fire emission calculation
- Atmospheric constraints indicate that WRF-Chem with FINN fire emissions tends to overestimate CO
- More pronounced CO estimations expected when using FireCCI-derived burned area products or GFED4s

Next steps:

- Perform model simulations using GFED4 and FireCCI-derived fire emissions
- Perform detailed model evaluation with satellite & aircraft observations
- Understand causes for observed biases → constrain fire emissions

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