From burned area to emissions

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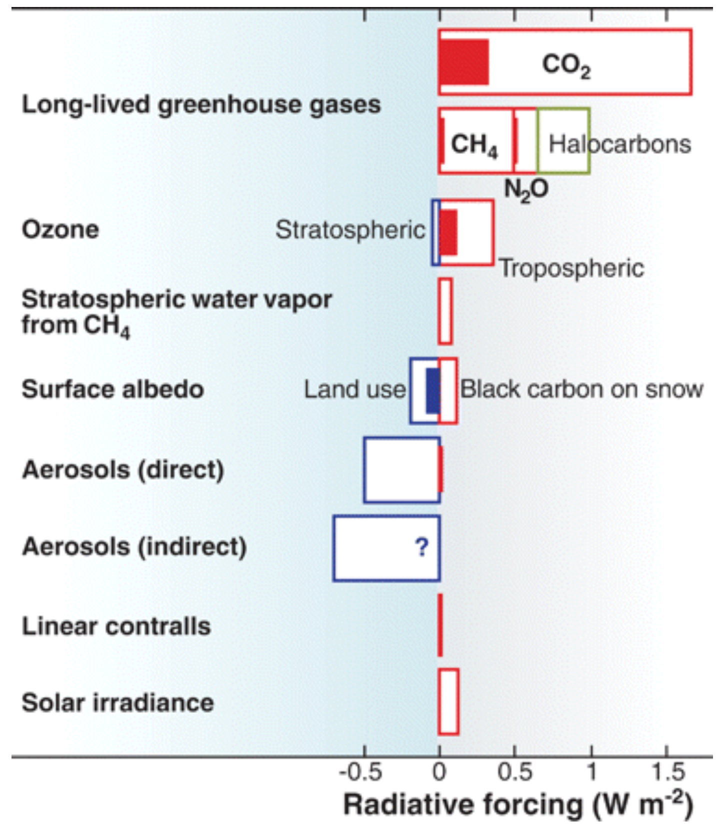
Why do we need emissions estimates?

- Fires are a major source of pollutants
  - Air quality (ozone, PM)
  - Atmospheric chemistry
  - Aerosol – cloud interactions
  - Aerosol deposition on snow

- Fires emit greenhouse gases
  - All fires emit methane and N_2O
    - From a climate change perspective a *change* in fire regimes is key
  - All fires emit CO_2
    - Fires in deforestation or degradation are a net source (REDD)
    - Fires in areas that see an increase in fire activity may also contribute to the build-up of CO_2



Bowman et al., 2009

History of estimating fire emissions

- Global scale estimates from in 1980s and 1990s based on biome-averaged fire return times and fuel loads (*Seiler, Crutzen, Andreae, Hao*)

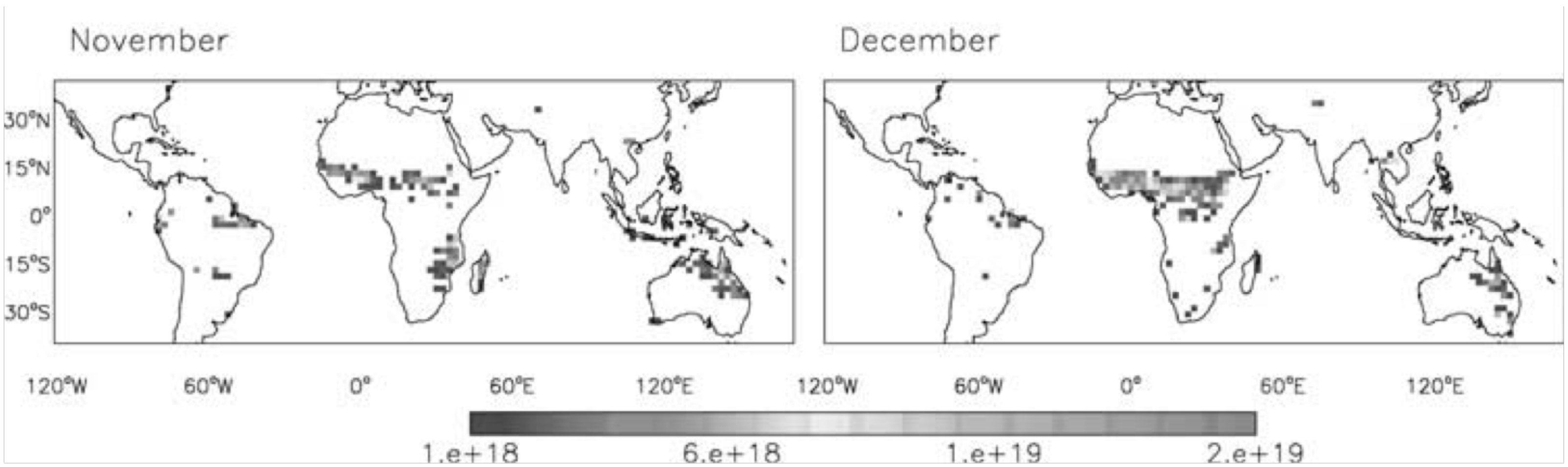
TABLE VI: Summary of data for the annually burned area and biomass (units: 100 Tg dry matter and millions of hectares; to convert dry matter to carbon multiply by 0.45). Data in brackets represent average values.

Activity	Burned and/or cleared area	Total biomass cleared	Biomass exposed to fire	Annually burned biomass	Dead below-ground biomass	Dead unburned above-ground biomass
Burning due to shifting agriculture	21–62 (41)	31–92 (62)	24–72 (48)	9–25 (17)	7–20 (14)	16–72 (44)
Deforestation due to population increase and colonization	8.8–15.1 (12.0)	20–33 (26.5)	16–25 (20.5)	5.5–8.8 (7.2)	4.0–8.0 (6.0)	10.5–16.0 (13.3)
Burning of savanna and bushland	(600)		12.2–23.8 (18)	4.8–19 (11.9)	8–16 (12)	2.4–4.8 (3.6)
Wildfires in temperate forests	3.0–5.0 (4.1)	10.5–17.5 (14.0)	7.7–12.8 (10.3)	1.5–2.6 (2.1)	2.8–4.7 (3.8)	6.2–10.2 (8.2)
Prescribed fires in temperate forests	2.0–3.0 (2.5)	1.2–1.8 (1.5)	0.3–0.5 (0.4)	0.1–0.2 (0.2)	0.6–0.9 (0.8)	0.2–0.3 (0.3)
Wild fires in boreal forests	1.0–1.5 (1.3)	2.5–3.8 (3.2)	1.8–2.7 (2.3)	0.4–0.6 (0.5)	0.7–1.1 (0.9)	1.4–2.1 (1.8)
Burning of industrial wood and fuel wood		31–32 (31.5)	11–12 (11.5)	10–11 (10.5)	5.5	1[1]
Burning of agricultural wastes			19–23 (21)	17–21 (19)	27–31 (29)	1.9–2.3 (2.1)
Total	630–690 (660)	130–250 (180)	92–172 (132)	48–88 (68)	56–87 (72)	40–109 (74)

[1] Excluding wood used in long lasting structures

History of estimating fire emissions

- Active fires from satellite (fire counts, hotspots) enabled distribution of global total in time and space in early 2000s (*Duncan, Schultz*)



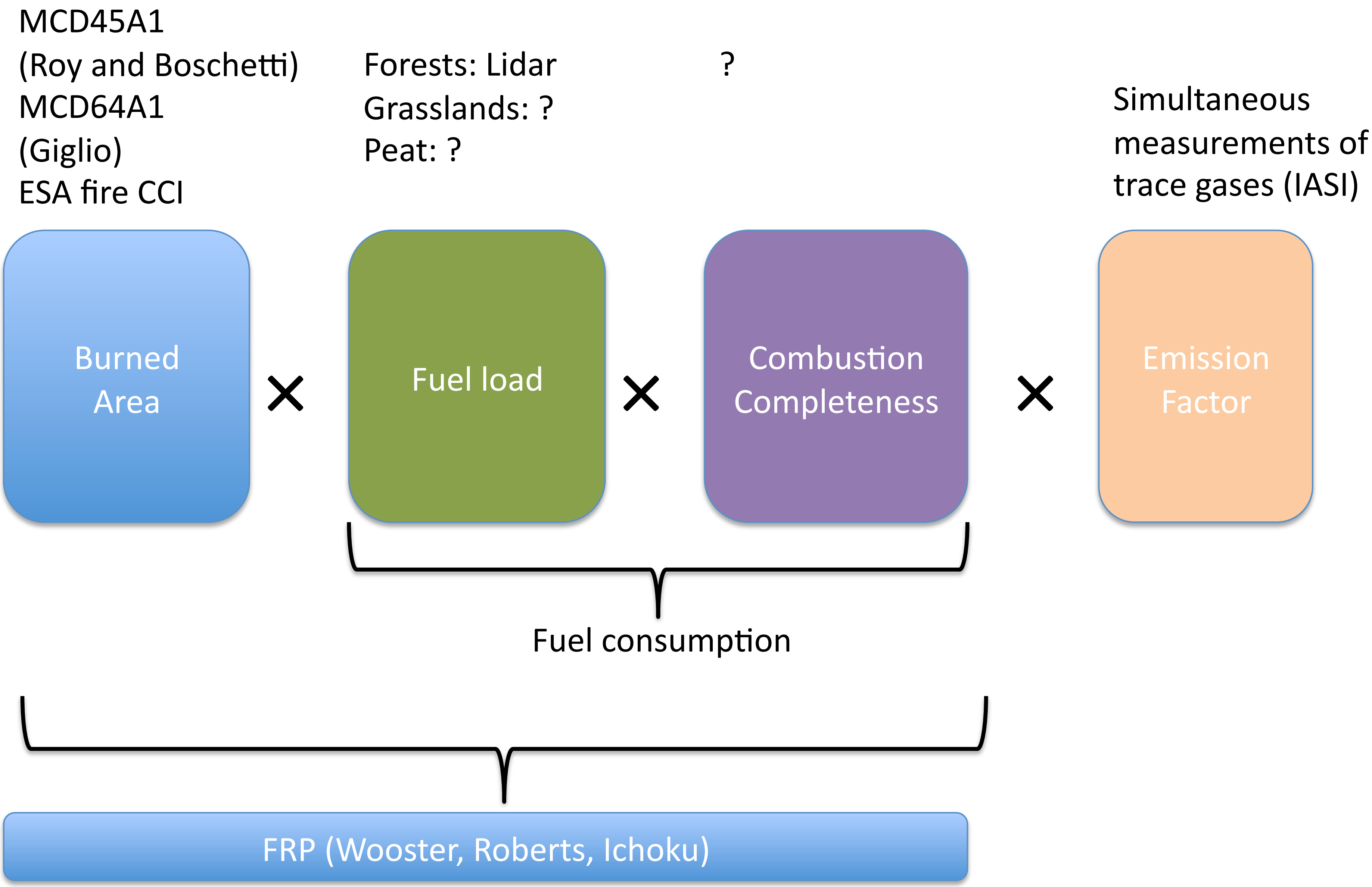
History of estimating fire emissions

- Modeling global emissions based on *Seiler and Crutzen equation* in time and space
  - Native resolution burned area in combination with land cover maps (*Ito, Liousse*)
  - Coarse resolution biogeochemical model (*Lehsten, van der Werf*) where fire is modeled as a potential carbon loss pathway
  - DGVM's driven by satellite burned area (*Hoelzemann, Thonicke, Kloster, Prentice*)
  - Active fire counts and land cover map (*Wiedinmeyer*). NRT

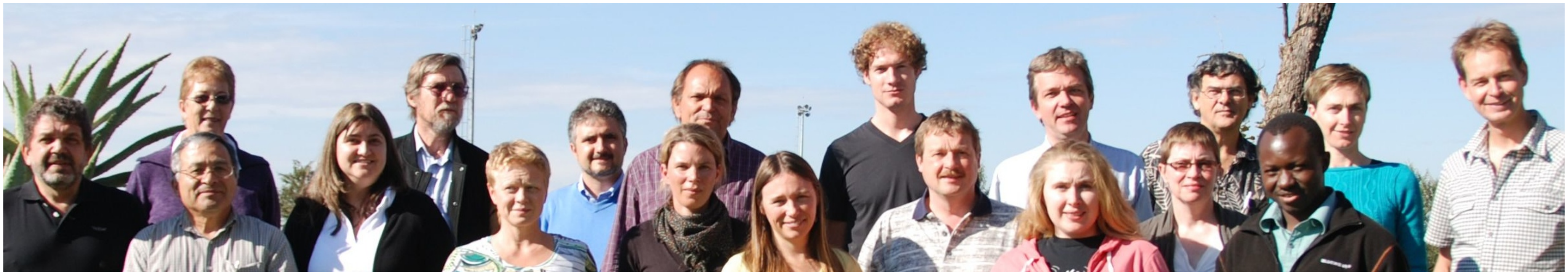
- Fire radiative power (*Wooster, Roberts, Ichoku, Kaiser*). NRT

- Modeling emissions on regional scale based on regional knowledge (DeGroot, Meyer, Krishna)

Current situation



South Africa workshop



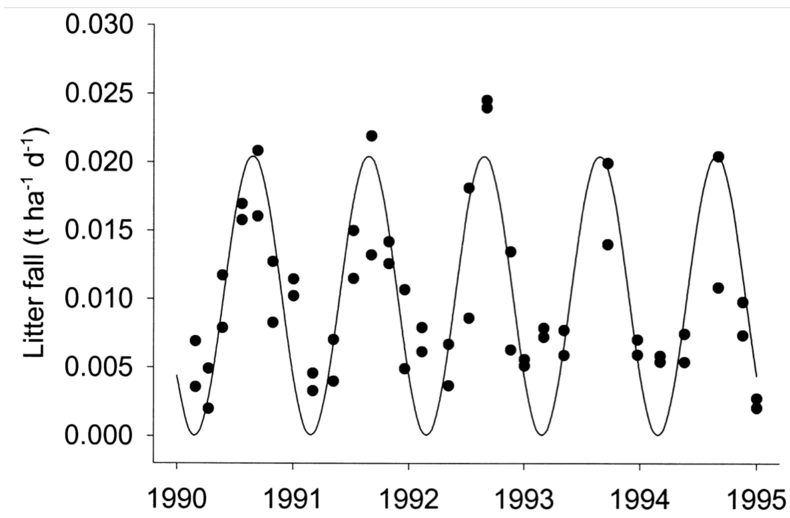
Workshop held after Wildfire 2011 conference in May

Sponsored by: EU FP7 “Coordination Action on Carbon Observation Systems” (COCOS)
GOFC-GOLD

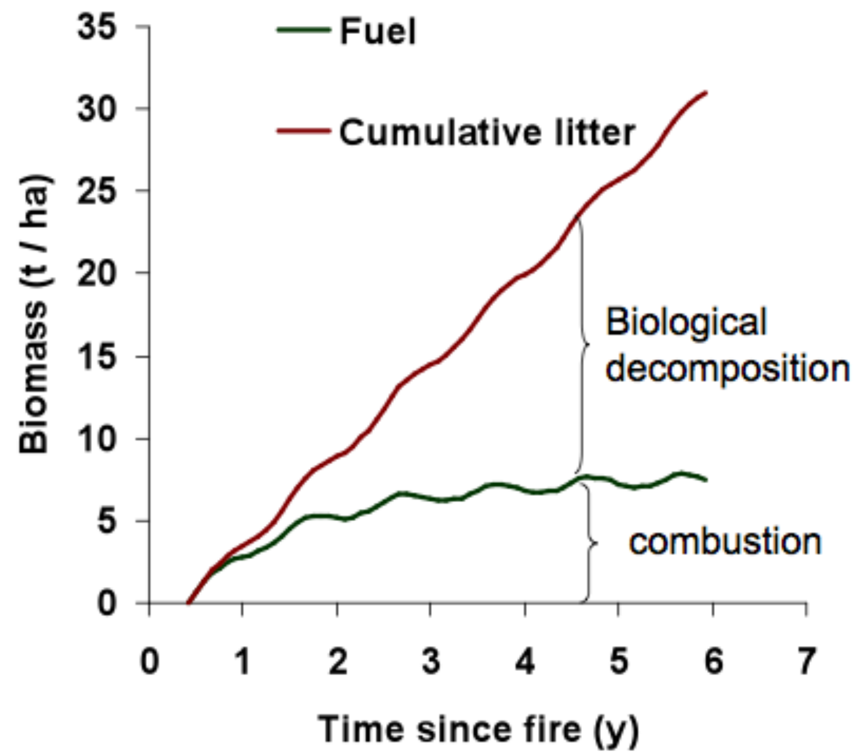
Reference	URL	Latitude	Longitude	Year	Month	Day	Continent	Fuel load	CC	Fuel consumption	Additional information
								Mg DM / ha	(-)	Mg DM / ha	
Cook et al., 2003-2009		-12.30	133.00	1990s	Early dry season		Australia	3.30	0.74	2.44	Minimum FL. Annual burn
Cook et al., 2003-2009		-12.30	133.00	1990s	Early dry season		Australia	5.70	0.74	4.22	Maximum FL. Annual burn
Cook et al., 2003-2009		-12.30	133.00	1990s	Early dry season		Australia	3.30	0.86	2.84	Minimum FL. Annual burn
Cook et al., 2003-2009		-12.30	133.00	1990s	Early dry season		Australia	5.70	0.86	4.90	Maximum FL. Annual burn
Cook et al., 2003-2009		-12.30	133.00	1990s	Early dry season		Australia	8.30	0.74	6.14	Long unbunt Australian tro
Cook et al., 2003-2009		-12.30	133.00	1990s	Early dry season		Australia	8.30	0.86	7.14	Long unbunt Australian tro
Ward et al., 1992	http://www.agu.o	-47.53	-15.51	1990	August-September		Brazil	7.10	1.00	7.10	
Ward et al., 1992	http://www.agu.o	-47.53	-15.51	1990	August-September		Brazil	7.30	0.97	7.08	
Ward et al., 1992	http://www.agu.o	-47.53	-15.51	1990	August-September		Brazil	8.60	0.72	6.19	
Ward et al., 1992	http://www.agu.o	-47.53	-15.51	1990	August-September		Brazil	10.00	0.84	8.40	
Shea et al., 1996	http://europa.agu	-25.15	31.14	1992	August		Africa	4.78	0.87	4.16	Biennial burning
Shea et al., 1996	http://europa.agu	-25.15	31.14	1992	August		Africa	3.91	0.44	1.72	Biennial burning
Shea et al., 1996	http://europa.agu	-25.15	31.14	1992	August		Africa	3.56	0.76	2.70	Biennial burning
Shea et al., 1996	http://europa.agu	-25.15	31.14	1992	August		Africa	4.44	0.84	3.73	Biennial burning
Shea et al., 1996	http://europa.agu	-25.15	31.14	1992	September		Africa	2.22	0.67	1.49	Biennial burning
Shea et al., 1996	http://europa.agu	-25.15	31.14	1992	September		Africa	3.94	0.96	3.78	Biennial burning
Shea et al., 1996	http://europa.agu	-12.35	30.21	1992	August	25	Africa	3.16	0.99	3.13	Dambo grassland
Shea et al., 1996	http://europa.agu	-12.35	30.21	1992	August	24	Africa	5.77	0.74	4.27	Miombo woodland
Shea et al., 1996	http://europa.agu	-12.35	30.21	1992	August	27	Africa	7.34	0.71	5.21	Fallow chitimene
Shea et al., 1996	http://europa.agu	-12.35	30.21	1992	September	3	Africa	5.10	0.88	4.49	Semiarid miombo woodlar

- Savanna
- Tropical forest
- Peat (tropical, temperate)
- Temperate forest
- Agriculture
- Boreal forest

Some highlights (Australian savanna)

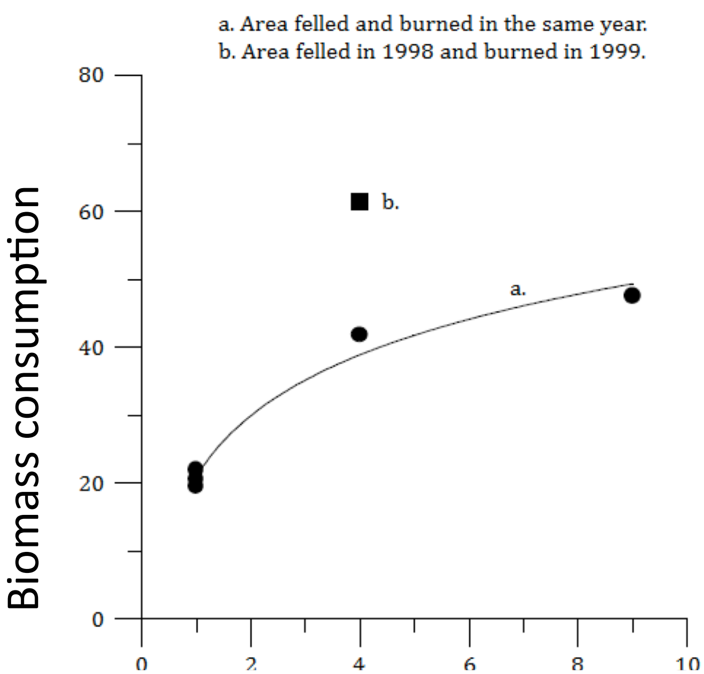


Cook et al. (2003)



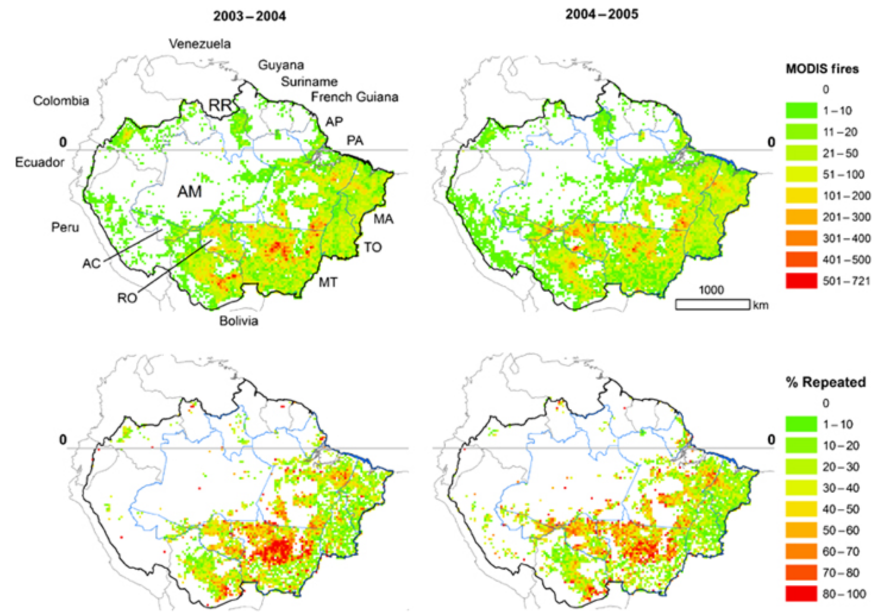
Biomass = litterfall / k $(1-e^{-kt})$

Some highlights (tropical forest)



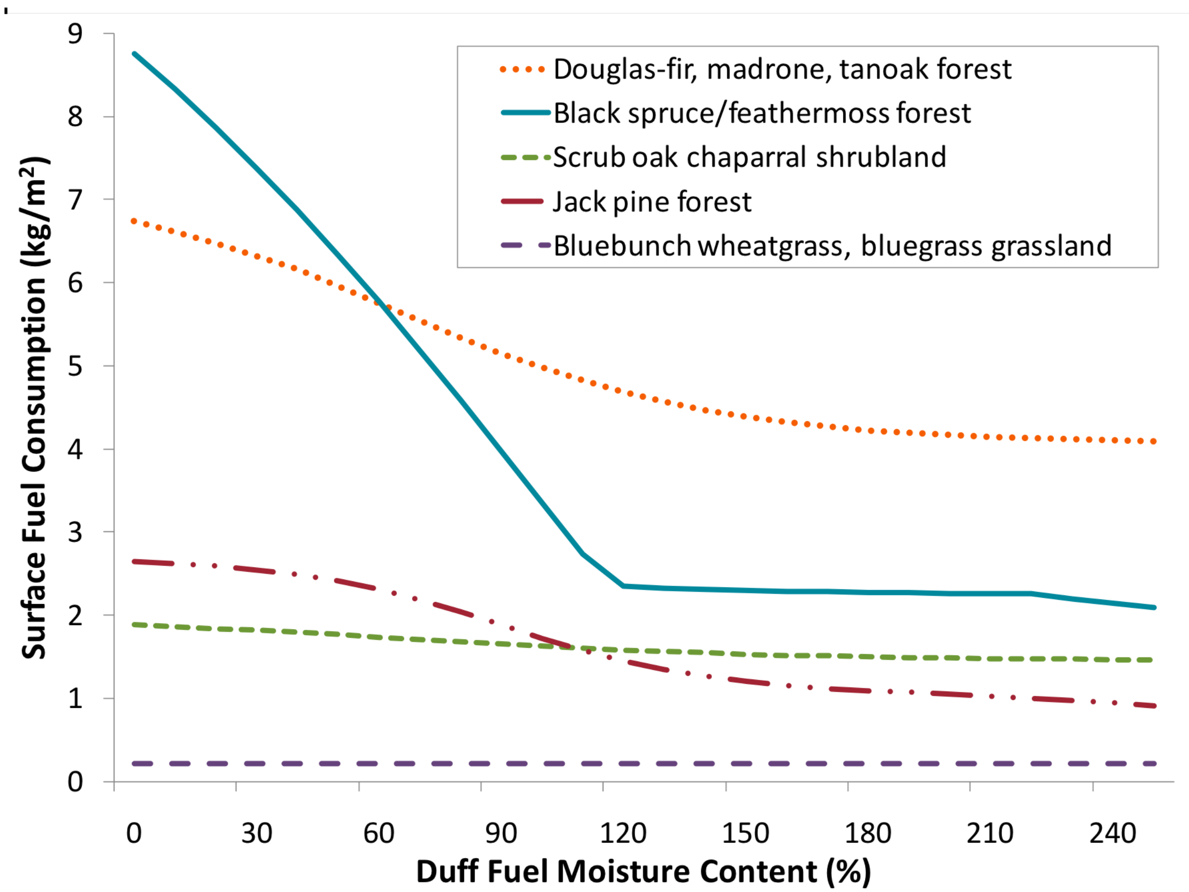
Deforested area (ha)

Carvalho et al. (2001)



Morton et al. (2008)

Some highlights (Boreal / Temperate)



CONSUME model

The Wildland Fire Emissions Information System (WFEIS), http://wfeis.mtri.org/

Some preliminary (and not very surprising) conclusions

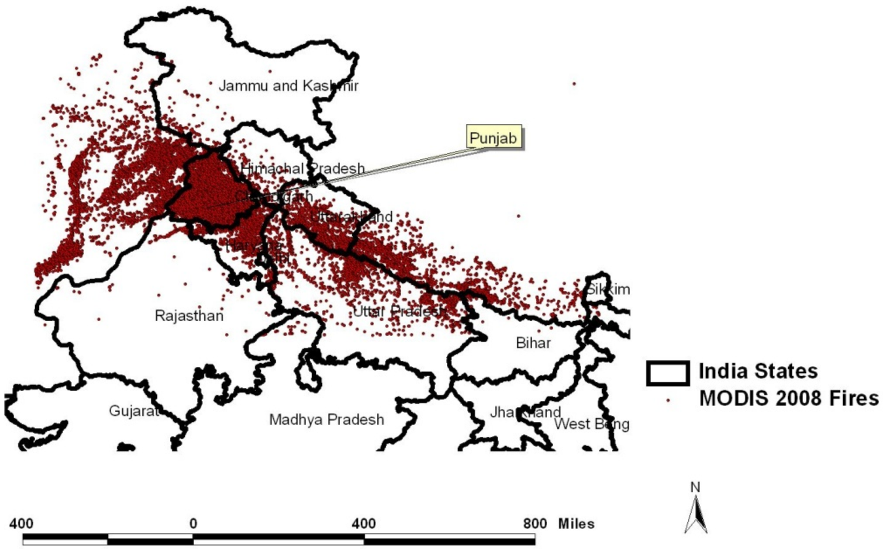
- Grass-dominated landscapes and tree-dominated landscapes require radically totally different modeling approaches
  - Grasslands:
    - time since last burn, grazing rates, fuel continuity, etc
    - fuel load varies, combustion completeness is "fixed"
  - Forests:
    - weather, tree species, disturbance history, climate, etc
    - Fuel load is "fixed", combustion completeness varies

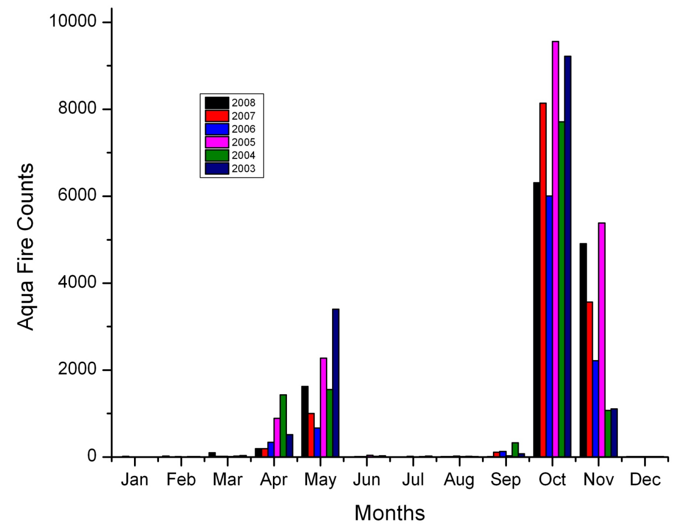
- Spatial and temporal variability is huge, also within biomes

Deliverables

- White paper (online October 31st)
- Database with fuel consumption estimates
  - Highlight regional differences (Australia vs Africa)
  - Various key drivers
  - Useful to validate models
  - Useful for FRP validation (FRP / burned area should give fuel consumption)
- Publication(s) summarizing main findings and regional differences (2012)

Work of Krishna and Dr. Badarinath *MODIS Fires*





Punjab, India in the study area domain had the highest fire counts

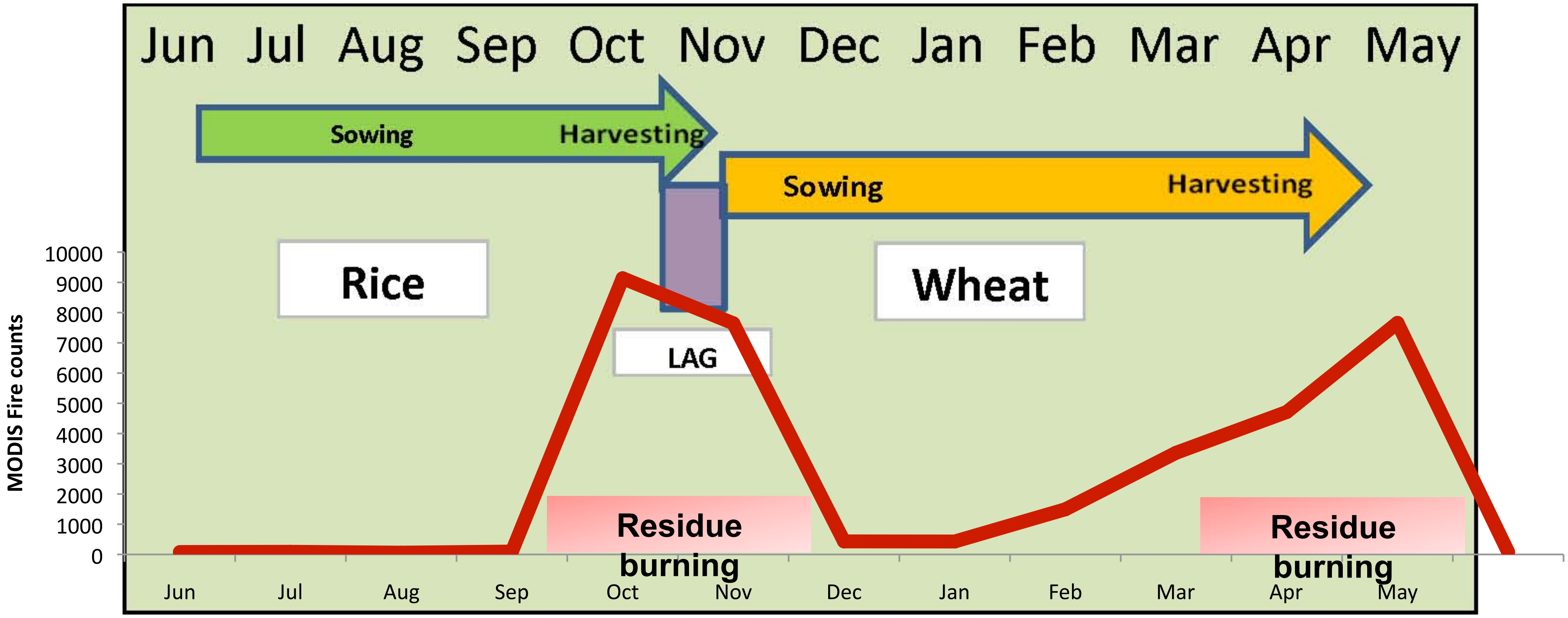
Bi-modal trend in Fire season April-May and Oct-Nov. Peaks correspond to Ag.residue burning.

2008 Total Fire counts – 35318

Aqua – 23601 (66.82%) – Satellite pass (2.00 pm)

Terra – 11717 (33.18%) - Satellite pass (11.00 am)

Bimodal trend correspond to Rice-Wheat Residue Burning

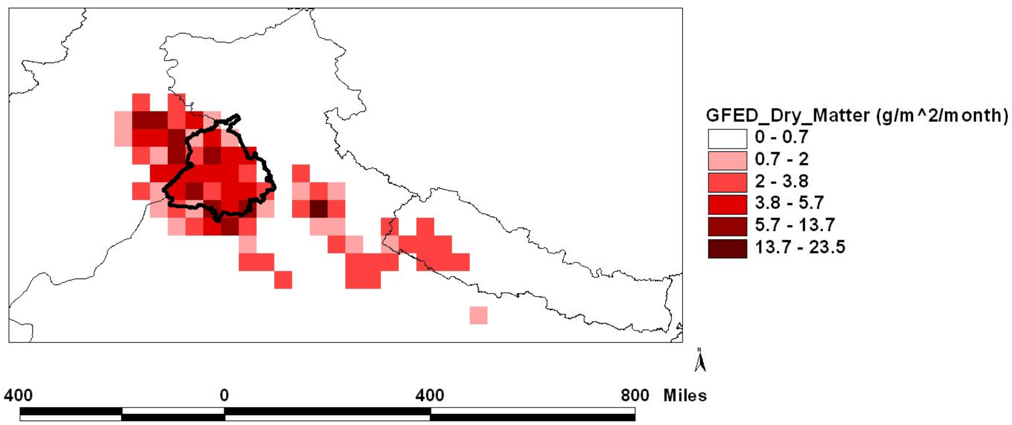


The main rice growing season is the 'Kharif'. It is known as Winter rice as per the harvesting time. The sowing time of winter (Kharif) rice is July-August and is harvested in October-November.

Wheat is sown during November-December and harvested during April-May.

High fire counts from MODIS correspond to Residue burning season.

Comparison of Fuel Loads in GFED vs. Actual Crop Data in Punjab, India dominated (95%) by Rice-Wheat Agriculture



Mean = 4.925 g/m2/month

IPC C methodology for estimating Residue amounts in the field:

Crop Production X Residue to Crop Ratio X Dry matter Fraction

GFED based dry matter values seems to be relatively low for Agricultural region of Punjab, which is the hotspot

Year	Wheat Area (ha)	Production (tons)	Residue fraction	Dry matter	g/m2/month
1996-97	3229000	13672000	1.5	0.83	43.93
1997-98	3300000	12715000	1.5	0.83	39.98
1998-99	3338000	14460000	1.5	0.83	44.94
1999-2000	3388000	15910000	1.5	0.83	48.72
2000-01	3408000	15551000	1.5	0.83	47.34
2001-02	3420000	15499000	1.5	0.83	47.02
2002-03	3375000	14175000	1.5	0.83	43.58
2003-04	3444000	14489000	1.5	0.83	43.65
2004-05	3482000	14698000	1.5	0.83	43.79
2005-06	3468000	14493000	1.5	0.83	43.36
2006-07	3467000	14596000	1.5	0.83	43.68
2007-08	3488000	15720000	1.5	0.83	46.76
					44.54

Year	Rice Area (ha)	Production	Residue fraction	Dry matter	g/m2/month
1996-97	2159000	7334000	1.5	0.83	35.24
1997-98	2281000	7904000	1.5	0.83	35.95
1998-99	2519000	7940000	1.5	0.83	32.70
1999-2000	2604000	8716000	1.5	0.83	34.73
2000-01	2611000	9154000	1.5	0.83	36.37
2001-02	2487000	8816000	1.5	0.83	36.78
2002-03	2530000	8880000	1.5	0.83	36.42
2003-04	2614000	9656000	1.5	0.83	38.32
2004-05	2647000	10437000	1.5	0.83	40.91
2005-06	2642000	10193000	1.5	0.83	40.03
2006-07	2621000	10138000	1.5	0.83	40.13
2007-08	2610000	10489000	1.5	0.83	41.69
					37.43

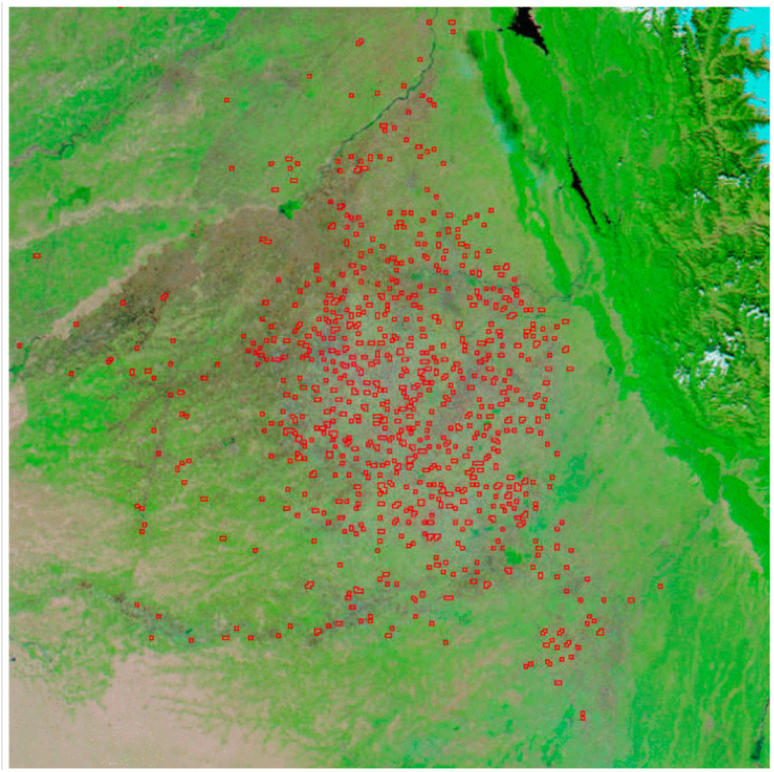
Comparison of Emission Factors from Tropical Evergreen Forest

BC for Extratropical Forest: Andreae and Merlet (2001) - 0.66 ± 0.31
BC from Tropical Evergreen Forest Biomass burning – 0.99 ±0.3

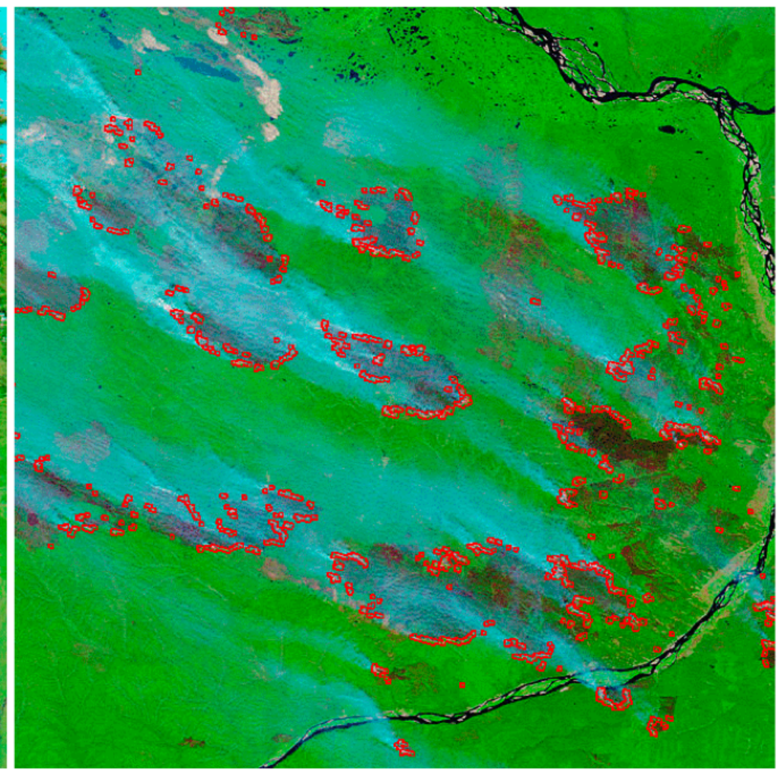
GFED update (version 3)

- MODIS MCD64A1 aggregated to 0.5d + MODIS/ATSR/ TRMM active fires to fill gaps and 1996-2001
- Active fires used to boost burned area and combustion completeness in deforestation zones
- CASA biogeochemical modeling for fuel loads and CC
- 0.5d (was 1d)
- Partitioning into sources
- Daily temporal resolution (Aqua onwards)
- Mean diurnal cycle
- *GFED4: 0.25d + 500-meter (at least tropics)*

Small fires



India
(agriculture / fragmented landscape)



Siberia
(Natural landscape)

Giglio et al. (2006)

Bottom-up / Top-down

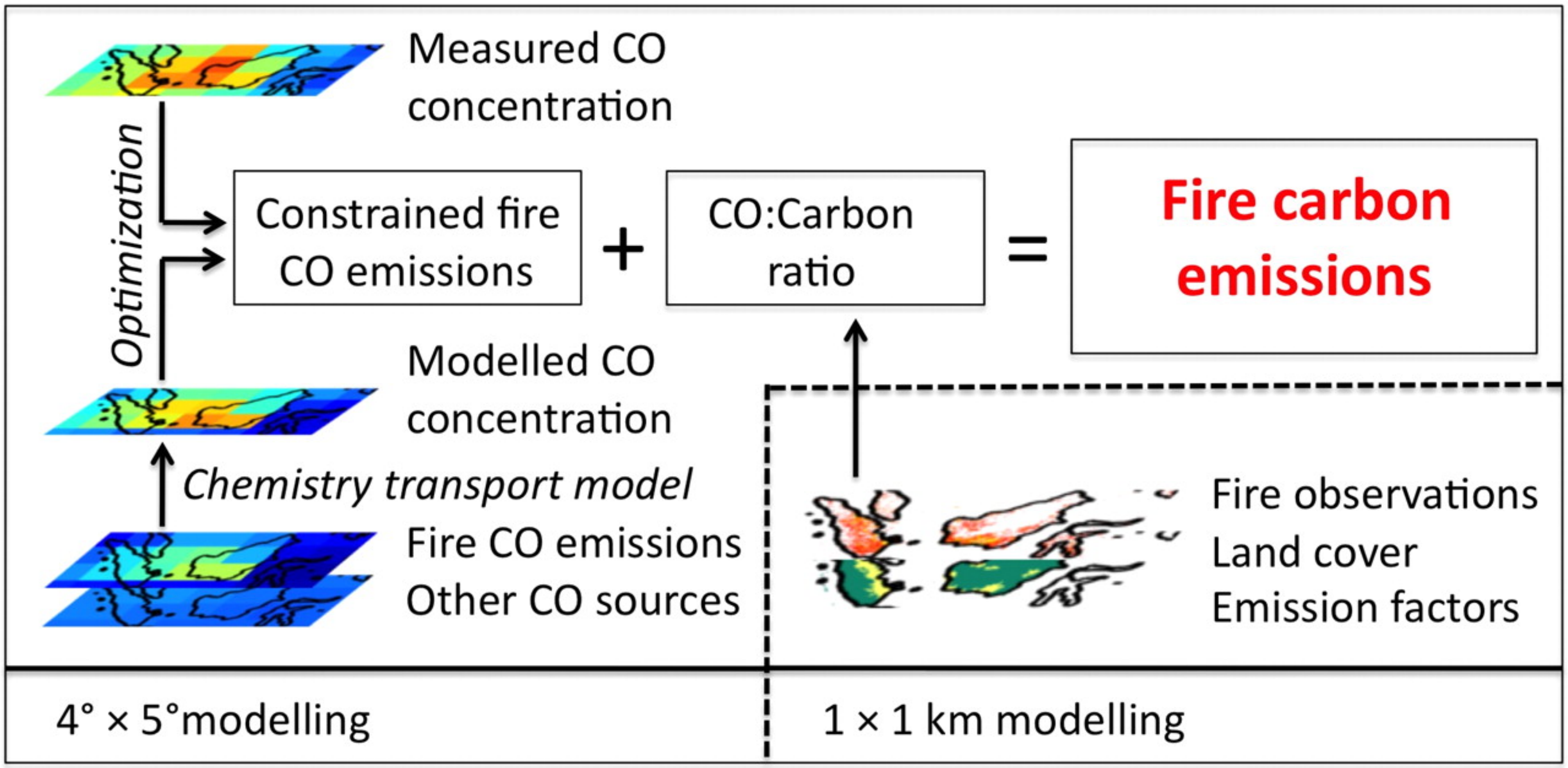
1. Fires emit trace gases and aerosols into the atmosphere

2. The resulting atmospheric concentrations can be predicted when injection height, atmospheric transport, and chemistry are taken into account

3. Concentrations of trace gases and aerosols are monitored from the surface and from satellite

4. Comparing predicted and observed concentrations yields independent validation on bottom-up emissions

Bottom-up / Top-down



Van der Werf et al. (2008)

Bottom-up / Top-down: issues

- Convection
  - Often underestimated, biasing concentrations to the surface
  - Injection height
  - Especially important for aerosols (which rain out)
  - Diurnal cycle
- Atmospheric transport in tropics far from perfect
- Emission factors: spatial and temporal variability

Bottom-up / Top-down: issues

- Powerful tool
  - Identify areas with large discrepancies
  - Identify areas with special emission factors (peatlands)
- Errors in atmospheric transport, chemistry, and observations (column) may be larger than errors in some bottom-up inventories
- Yields guidance, but no certainty and leads to the risk of being right for the wrong reasons