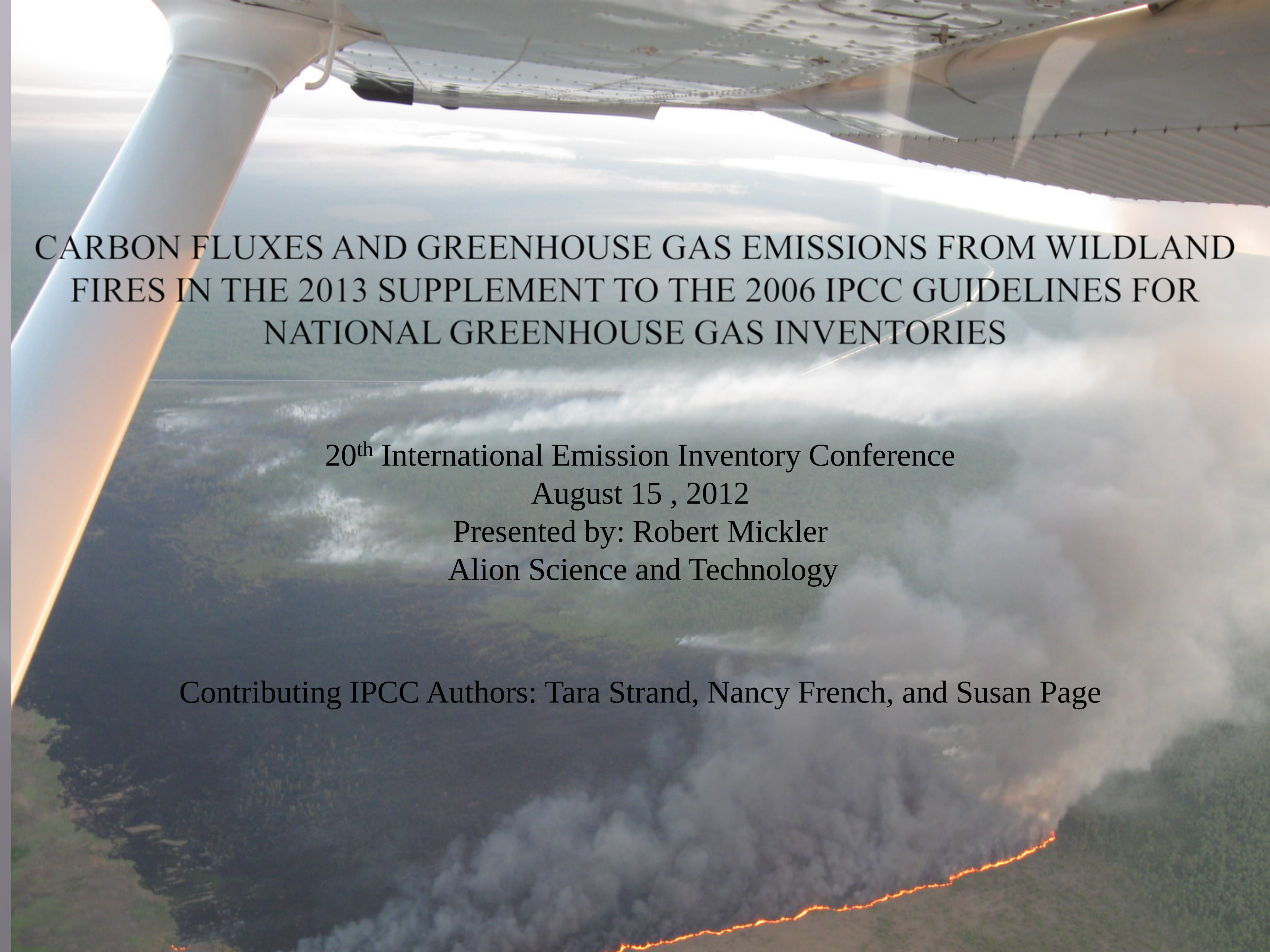


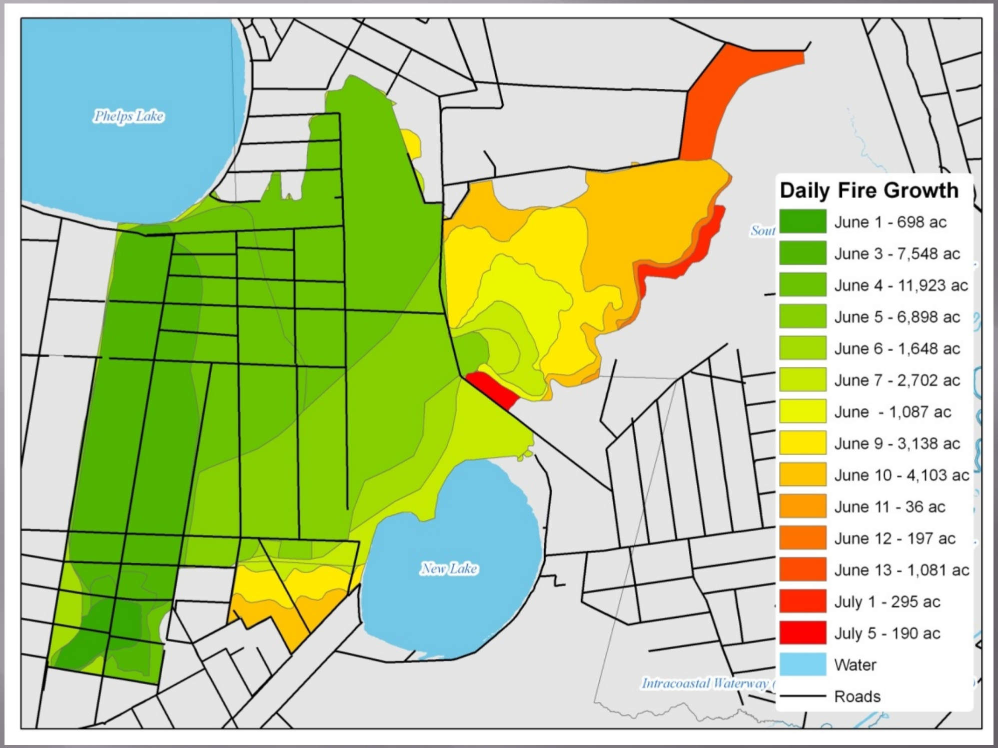
CARBON FLUXES AND GREENHOUSE GAS EMISSIONS FROM WILDLAND FIRES IN THE 2013 SUPPLEMENT TO THE 2006 IPCC GUIDELINES FOR NATIONAL GREENHOUSE GAS INVENTORIES

20th International Emission Inventory Conference
August 15 , 2012
Presented by: Robert Mickler
Alion Science and Technology

Contributing IPCC Authors: Tara Strand, Nancy French, and Susan Page


Coastal Plain Vegetation and
Organic Soil Groundfire

Evans Road Fire Chronology



The chronology of the Evans Road Fire :

June 1, 2008 – Fire starts from lightning strike

June 2, 2008 – NC IMT dispatched to 700 acre fire

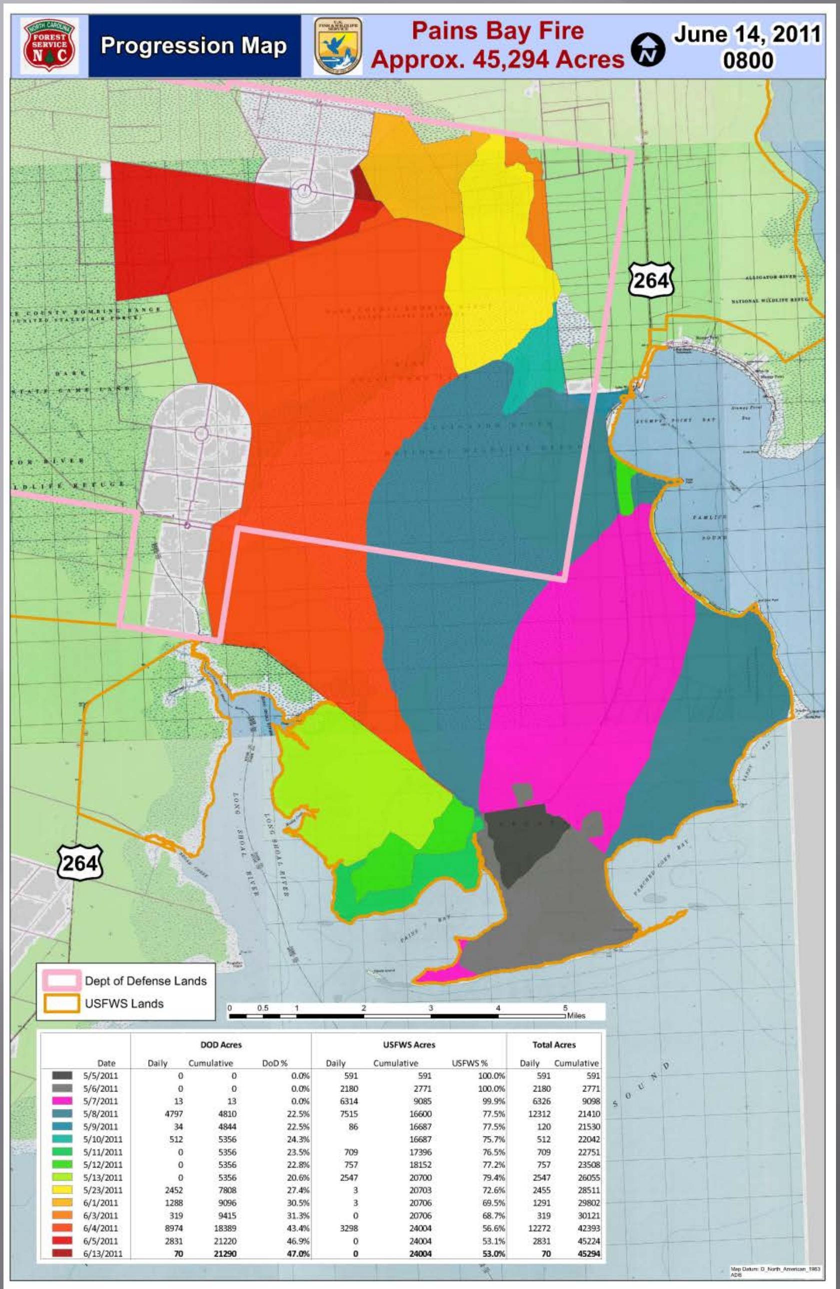
June 3, 2008 – Team arrives to 1,250 acre fire

June 4, 2008 – Team goes to bed managing 8,000 acre fire

June 14, 2008 – The fire had reached 40,704 acres in size

June 3 to August 8, 2009 – Six Type 2 Incident Management Teams managed the Evans Road fire.

January 9, 2009 – Evans Road Fire declared out at a cost of $20 Million



	Date	DOD Acres Daily	DOD Acres Cumulative	DoD %	USFWS Acres Daily	USFWS Acres Cumulative	USFWS %	Total Acres Daily	Total Acres Cumulative
	5/5/2011	0	0	0.0%	591	591	100.0%	591	591
	5/6/2011	0	0	0.0%	2180	2771	100.0%	2180	2771
	5/7/2011	13	13	0.0%	6314	9085	99.9%	6326	9098
	5/8/2011	4797	4810	22.5%	7515	16600	77.5%	12312	21410
	5/9/2011	34	4844	22.5%	86	16687	77.5%	120	21530
	5/10/2011	512	5356	24.3%		16687	75.7%	512	22042
	5/11/2011	0	5356	23.5%	709	17396	76.5%	709	22751
	5/12/2011	0	5356	22.8%	757	18152	77.2%	757	23508
	5/13/2011	0	5356	20.6%	2547	20700	79.4%	2547	26055
	5/23/2011	2452	7808	27.4%	3	20703	72.6%	2455	28511
	6/1/2011	1288	9096	30.5%	3	20706	69.5%	1291	29802
	6/3/2011	319	9415	31.3%	0	20706	68.7%	319	30121
	6/4/2011	8974	18389	43.4%	3298	24004	56.6%	12272	42393
	6/5/2011	2831	21220	46.9%	0	24004	53.1%	2831	45224
	6/13/2011	**70**	**21290**	**47.0%**	**0**	**24004**	**53.0%**	**70**	**45294**

Pains Bay Fire Chronology

The chronology of the Pains Bay Fire :

May 4, 2011 – Fire starts from lightning strike near Pains Bay
May 6, 2011 – Fire jumps Hwy 264
May 7, 2011 – Fire enters the DCBR
May 8, 2011– Fire increases to 21,410 acres
May 10, 2011 – The fire is being managed by a Type 1 IMT
May 23, 2011 – Thirty mile per hour winds cause fire to jump low pocossin firelines and jump Jackson Rd.
June 3, 2011 – Backfire Bow Tie Tract
June 4, 2011 – Backfire east of Air Force Impact Area
June 5, 2011 – Fire jumps into Navy Impact Area. Backfire area.
June 14, 2011 – The fire had reached 45,294 acres in size with significant organic soil groundfire
July 19, 2011 – Fire declare 100% contained.
August 24, 2011 – Pains Bay Fire declared out at a cost of $14.2 Million

Evans Road Fire Organic Soil Consumption

Evans Road Fire
Post Fire Organic Soil
Groundfire

Evans Road Fire and Post-Fire Organic Soil Impacts

Pains Bay Fire

Post Fire Organic Soil Groundfire

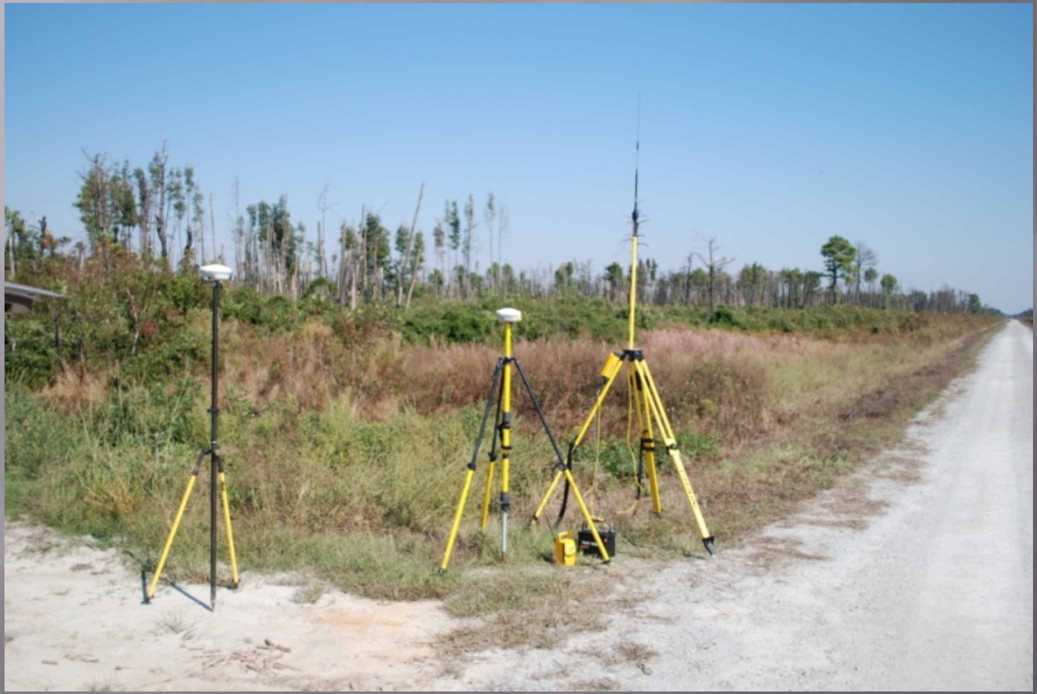
Evans Road Fire
3 Years Post Fire Vegetation

Pains Bay Fire
Fire Operations – Smoke and Smoke

Super Fog at Morning Fire Brief with church steeple in background and fire fighters in foreground

- Multiple super fog events and road closures
- NC DAQ Code Red Air Quality
- EPA Ambient Air Quality Standards for PM
- Smoke on highways and road closures

Trimble Survey Equipment
Base Station, Transmitter, and Rover



Organic Soil Carbon Emissions

Ranking	dNBR Category	Drainage Category	Ownership Category	Count of Points Collected	Carbon Emissions (Metric Tons)	Acres
1	3	Drained	Public	35	1,906,622.13	12,611.0
2	3	Drained	Private	37	3,607,045.35	10,240.4
3	2	Drained	Private	33	1,934,011.97	4,424.8
4	3	Undrained	Public	32	1,163,551.57	3,549.2
5	2	Drained	Public	34	272,861.51	3,373.8
6	2	Undrained	Public	43	357,531.43	2,847.1
7	0	Undrained	Public	19	-84,575.12	2,268.7
8	1	Undrained	Public	22	7,597.20	1,210.1
Unranked	-	-	-	-		1,018.7
Sum					9,164,646.04	41,543.7

The Evans Road wildfire contributed 9.1 Tg C below ground and 0.3 Tg C above ground emissions compared to average annual total carbon emissions estimated at 58 Tg C from wildfires in the US.

Wildfire vs. Prescribed Fire VOCs

EPA Method TO-15	Pains Bay Wildfire (Sm)	ARNWR Rx (Fl)	ARNWR Rx (Sm)	PLNWR Rx (Sm)	PLNWR Rx (Sm)
Dichlorodifluoromethane (Freon 12)	NF	0.47 ppbv	0.54 ppbv	NF	NF
Chloromethane	17.95 ppbv	2.66 ppbv	NF	NF	NF
Vinyl chloride	NF	NF	NF	NF	NF
1,3-Butadiene	9.32 ppbv	NF	NF	NF	NF
Bromomethane	4.41 ppbv	NF	NF	0.22 ppbv	NF
Trichloromonofluoromethane	NF	0.29 ppbv	0.28 ppbv	0.3 ppbv	NF
Ethanol	1.08 ppbv	2.35 ppbv	8.53 ppbv	4.26 ppbv	1.21 ppbv
Carbon disulfide	NF	NF	NF	4.06 ppbv	NF
Isopropyl alcohol	NF	1.38 ppbv	0.84 ppbv	1.26 ppbv	0.6 ppbv
Methylene chloride	NF	6.27 ppbv	3.97 ppbv	4.8 ppbv	2.65 ppbv
Acetone	74.56 ppbv	27.67 ppbv	NF	43.87 ppbv	9.22 ppbv
Hexane	15.02 ppbv	1 ppbv	0.93 ppbv	NF	NF
Vinyl acetate	2.05 ppbv	0.96ppbv	NF	NF	NF
Cyclohexane	2.24 ppbv	NF	NF	NF	NF
Ethyl Acetate	9.05 ppbv	0.61 ppbv	0.58 ppbv	NF	NF
2-Butanone	NF	2.65 ppbv	NF	NF	NF
Heptane	10.86 ppbv	NF	NF	NF	NF
Benzene	68.14 ppbv	9.4 ppbv	3.23 ppbv	1.05 ppbv	1.59 ppbv
Trichloroethylene	NF	NF	NF	NF	0.66 ppbv
Toluene	28.75 ppbv	5.54 ppbv	1.98 ppbv	1.74 ppbv	1.59 ppbv
Ethylbenzene	7.03 ppbv	NF	NF	0.53 ppbv	0.49 ppbv
Chlorobenzene	NF	NF	NF	NF	0.36 ppbv
m/p-Xylene	9.93 ppbv	2.49 ppbv	0.89 ppbv	1.78 ppbv	1.33 ppbv
o-Xylene	9.38 ppbv	0.76 ppbv	NF	0.59 ppbv	0.55 ppbv
Styrene	3.96 ppbv	0.95 ppbv	0.30	NF	NF
1-ethyl-4-methylbenzene	NF	0.67 ppbv	0.27 ppbv	NF	0.66 ppbv
1,3,5-trimethylbenzene	NF	0.68 ppbv	0.26 ppbv	0.26 ppbv	Below MDL
1,2,4-trimethylbenzene	2.30 ppbv	1.1 ppbv	NF	1.08 ppbv	0.76 ppbv
Benzyl chloride	1.97 ppbv	NF	NF	NF	NF

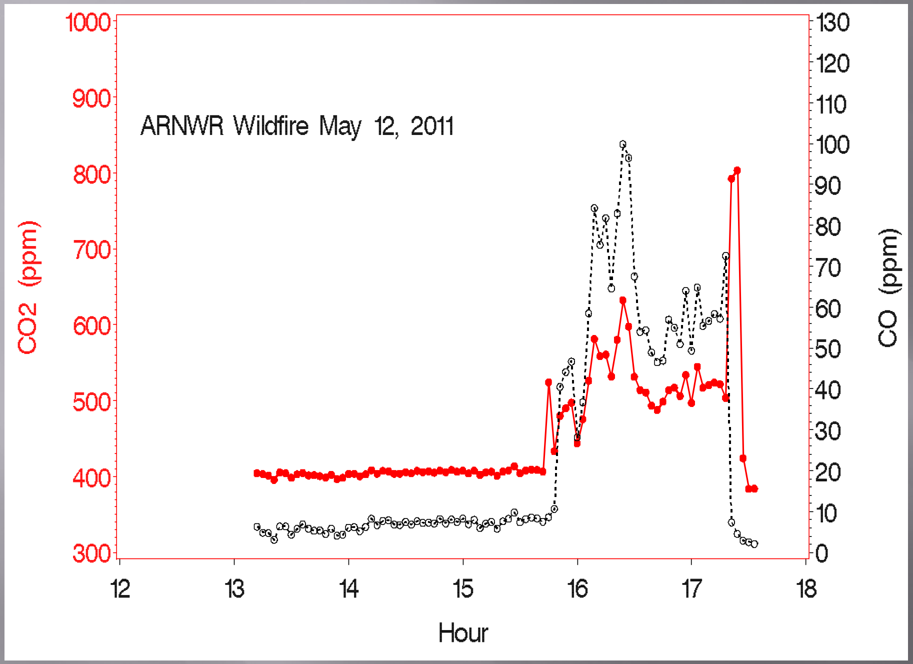
Acetone, benzene, and toluene had the highest concentrations for prescribed and wildfires.

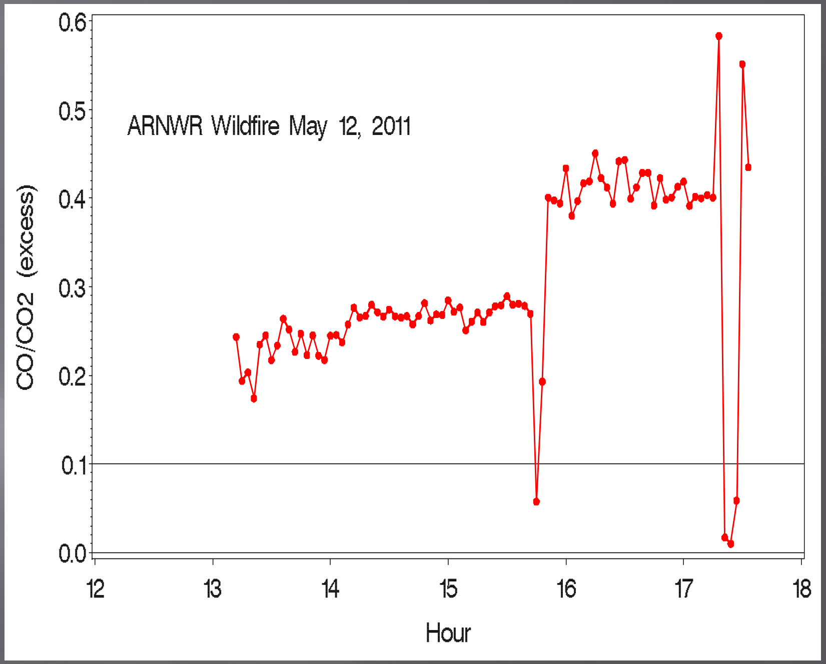
Wildfire vs. Prescribed Fire Aldehydes

	Pains Bay Wildfire (Sm)	ARNWR Rx (Fl)	ARNWR Rx (Sm)	PLNWR Rx (Fl)	PLNWR Rx (Sm)
EPA Method TO-11A/8315 HPLC					
Formaldehyde	**0.384 µg/L**	**0.066 µg/L**	**0.011 µg/L**	**0.061 µg/L**	**0.005 µg/L**
Acetaldehyde	**0.404 µg/L**	**0.038 µg/L**	**0.005 µg/L**	**0.035 µg/L**	**0.016 µg/L**
Acrolein & Acetone	**<0.001 µg/L**	**0.011 µg/L**	**0.004 µg/L**	**0.013 µg/L**	**0.009 µg/L**
Propionaldehyde	**0.236 µg/L**	**0.014 µg/L**	**0.002 µg/L**	**0.003 µg/L**	**<0.001 µg/L**
Crotonaldehyde	**<0.001 µg/L**	**0.002 µg/L**	**<0.001 µg/L**	**0.003 µg/L**	**<0.001 µg/L**
Butyraldehyde	**<0.001 µg/L**	**<0.001 µg/L**	**<0.001 µg/L**	**0.003 µg/L**	**0.001 µg/L**
Benzaldehyde	**0.090 µg/L**	**0.015 µg/L**	**0.002 µg/L**	**0.014 µg/L**	**<0.001 µg/L**
Isovaleradehyde	**0.207 µg/L**	**<0.001 µg/L**	**<0.001 µg/L**	**0.003 µg/L**	**<0.001 µg/L**
Valeradelhyde	**0.100 µg/L**	**0.005 µg/L**	**<0.001 µg/L**	**0.005 µg/L**	**<0.001 µg/L**
o-Tolualdehyde	**0.121 µg/L**	**0.028 µg/L**	**0.004 µg/L**	**0.002 µg/L**	**<0.001 µg/L**
m-Tolualdehyde	**<0.001 µg/L**	**<0.001 µg/L**	**<0.001 µg/L**	**0.026 µg/L**	**<0.001 µg/L**
p-Tolualdehyde	**0.031 µg/L**	**<0.001 µg/L**	**<0.001 µg/L**	**<0.001 µg/L**	**<0.001 µg/L**
Hexaldehyde	**<0.001 µg/L**	**0.002 µg/L**	**<0.001 µg/L**	**0.003 µg/L**	**<0.001 µg/L**
2,5-Dimethylbenzaldehyde	**<0.001 µg/L**	**0.006 µg/L**	**0.001 µg/L**	**0.003 µg/L**	**<0.001 µg/L**

Aldehydes concentrations were higher for the Pains Bay wildfire compared to the flaming and smoldering stages of prescribed fires on the same coastal forest ecosystems. The aldehyde concentrations for flaming stages of prescribed fires were higher than the smoldering stage. Formaldehyde and acetaldehyde were the major compounds for the smoldering and flaming stages of prescribed and wild fires.

Pains Bay Fire CO_2 and CO





Measurements made after hour 15.6 were dominated by an organic soil burning source. CO/CO_2 values of 0.2 and 0.4 are much higher than typically observed from burning of above-ground fuels which range from 0.03 to ~ 0.15. This indicates much lower combustion efficiency, which is conducive to high PM and reduced trace gas emissions. $PM_{2.5}$ EFs were also a factor of 4-10 higher than published above ground rates, and ranged from 36 to 65 g kg^{-1}.

Prescribed Fire Emission Factors

			Emission Factors in g/kg (fuel dry weight) % of $PM_{2.5}$											
Location	Stage	Time	PM_{10}	$PM_{10}M$	$PM_{2.5}$	$PM_{2.5}Q$	$PM_{2.5}M$	CO	CO_2	CO_2c	NO_x	THC	SO_2	LG
ARNWR Stumpy Pt.	Fl	11:08-12:25	1.42	1.17	NA	0.86	0.63	15.6	1680	1740	0.71	45.7	1.06	6.3 (0.6)
PLNWR	Fl/Sm	14:15-14:47	8.13	11.0	NA	6.12	4.40	168	1530	1560	0.00	8.8	0.23	8.3 (1.3)
Croatan NF	Fl/Sm	14:40-15:10	5.48	5.39	5.40	4.14	3.72	168	1530	1680	6.69	12.7	1.57	2.7 (1.1)
Croatan NF	Fl	15:15-16:00	1.13	0.94	0.67	0.61	0.64	32.1	1770	1690	1.08	4.3	0.29	NA
Croatan NF	Fl	16:00-16:40	0.61	0.48	0.47	0.32	0.38	22.3	1790	1660	0.56	3.3	0.22	NA
Croatan NF	Sm	16:55-18:20	1.43	0.80	1.12	0.99	0.62	34.7	1770	1610	0.79	6.0	0.24	2.6 (1.1)
ARNWR	Fl	11:41-13:02	6.49	2.92	6.49	4.87	2.22	44.2	1730	1700	2.07	10.1	0.55	4.6 (0.4)
ANRWR	Sm	13:47-16:30	3.38	1.67	2.07	2.41	0.84	34.1	950	920	0.81	303	0.43	1.5 (0.2)
Croatan NF	Fl/Sm	11:40-13:03	1.80	NA	1.67	1.63	NA	20.6	1660	1350	0.87	50.1	0.19	7.4 (0.9)
Green Swamp	Fl	12:05-13:35	NA	NA	8.02	8.67	NA	40.1	1750	NA	NA	20	NA	3.1 (0.4)
PLNWR	Fl	10:48-11:44	NA	NA	9.49	10.44	NA	61.0	1710	NA	NA	17	NA	4.5 (0.4)

$PM_{2.5}$ typically composes at least 2/3 of total ambient PM, and roughly 80% of PM_{10} from biomass combustion sources. In general, our $PM_{2.5}$ and PM_{10} EFs were lower or similar to those published in other open biomass burning studies. Organic soil burning $PM_{2.5}$ EFs can exceed 40 g kg^{-1}. Levoglucosan (LG), a sugar anhydride produced from cellulose combustion composed a high percentage of $PM_{2.5}$ in the Rx fire smoke , accounted for 3 to 10% of total $PM_{2.5}$ mass.

The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment

- Working Group I will issue “The Physical Science Basis” in mid-September 2013.
- Working Group II will issue “Impacts, Adaptation and Vulnerability” in mid-March 2014.
- Working Group III will issue “Mitigation of Climate Change” in early April 2014.
- The IPCC Fifth Assessment Report (AR5)” will be issued in October 2014.

At its 33rd session, the Intergovernmental Panel on Climate Change (IPCC) decided to produce additional guidance, the “2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands”, to cover both inland wetlands and coastal wetlands. The 2006 IPCC Guidelines themselves note that the guidance on wetlands is incomplete. Emissions inventory methodologies for prescribed and wildland fires were specifically identified as a knowledge gap.

Peat, Peaty, Peatland, Muck, Organic Soil, or Histosol
What is it?
3% of the Earth’s land area (400 Mha) and 15-30% global soil C stocks

FAO (2006/7) defines organic soils (Histosols) as: Soils having organic material, either:

1. 10 cm or more thick starting at the soil surface and immediately overlying ice, continuous rock, or fragmental materials, the interstices of which are filled with organic material; or
2. cumulatively within 100 cm of the soil surface either 60 cm or more thick if 75% (by volume) or more of the material consists of moss fibres or 40 cm or more thick in other materials and starting within 40 cm of the soil surface.

Organic material has one or both of the following:

1. 20% or more organic carbon in the fine earth (by mass); or
2. if saturated with water for 30 consecutive days or more in most years (unless drained), one or both of the following:

a. (12 + [clay percentage of the mineral fraction   0.1])% or more organic carbon in the fine earth (by mass); or

b. 18% or more organic carbon in the fine earth (by mass). The soils must constitute ‘a peat layer greater than 30 cm on drained peats and greater than 45 cm on undrained peats.‘

Or

IPCC (Chapter 3 Annex 3A.5 of the 2006 IPCC Guidelines) omits the 40 cm criterion from the FAO definition.

Greenhouse Gas Emissions
Are They a Stock or a Flux?

The IPCC Guidelines recommend two methods for to estimate greenhouse gas emissions:

1.)Net Changes in Carbon Stocks over time, or

2.) Gas Flux Rates to and from the atmosphere.

The Problem

Net Changes in Carbon Stocks - In managed organic soils the soil layer becomes thinner when degraded from drainage, oxidation, and compaction due to loss of pore water. The stock approach method must consider the entire depth of the organic soil layer, not just the top 30 centimeters.

Gas Flux Rates – Based on air tight chambers placed on the soil to assess gas concentrations with excluded vegetation and roots (Difficult), or eddy flux measurements for total ecosystem gas exchange with accounting for standing biomass and litter (Difficult and Expensive).

Estimation of Greenhouse Gas Emissions From Fire

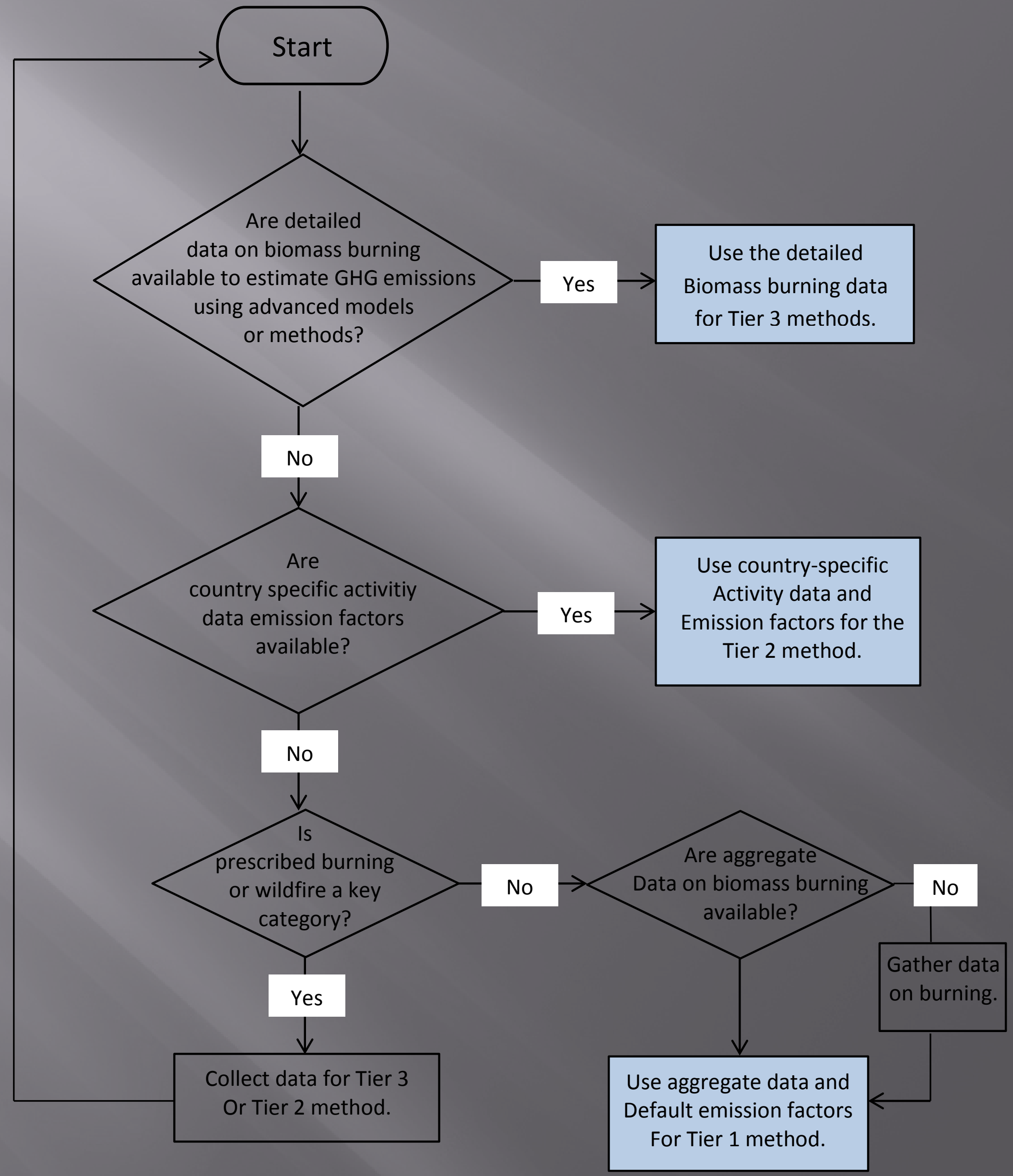
$$L_{fire} = A \cdot M_B \cdot C_f \cdot G_{ef} \cdot 10^{-3}$$

Where:

- L_{fire} = amount of greenhouse gas emissions from fire, tonnes of each GHG e.g., CH_4, N_2O, etc.
- A = area burnt, ha
- M_B = mass of fuel available for combustion, tonnes ha-1. This includes biomass, ground litter and dead wood. When Tier 1 methods are used then litter and dead wood pools are assumed zero, except where there is a land-use change
- C_f = combustion factor, dimensionless
- G_{ef} = emission factor, g kg-1 dry matter burnt

Note: Where data for M_B and C_f are not available, a default value for the amount of fuel actually burnt (the product of M_B and C_f) can be used under Tier 1 methodology.

Generic Decision Tree to Estimate Greenhouse Gas Emissions

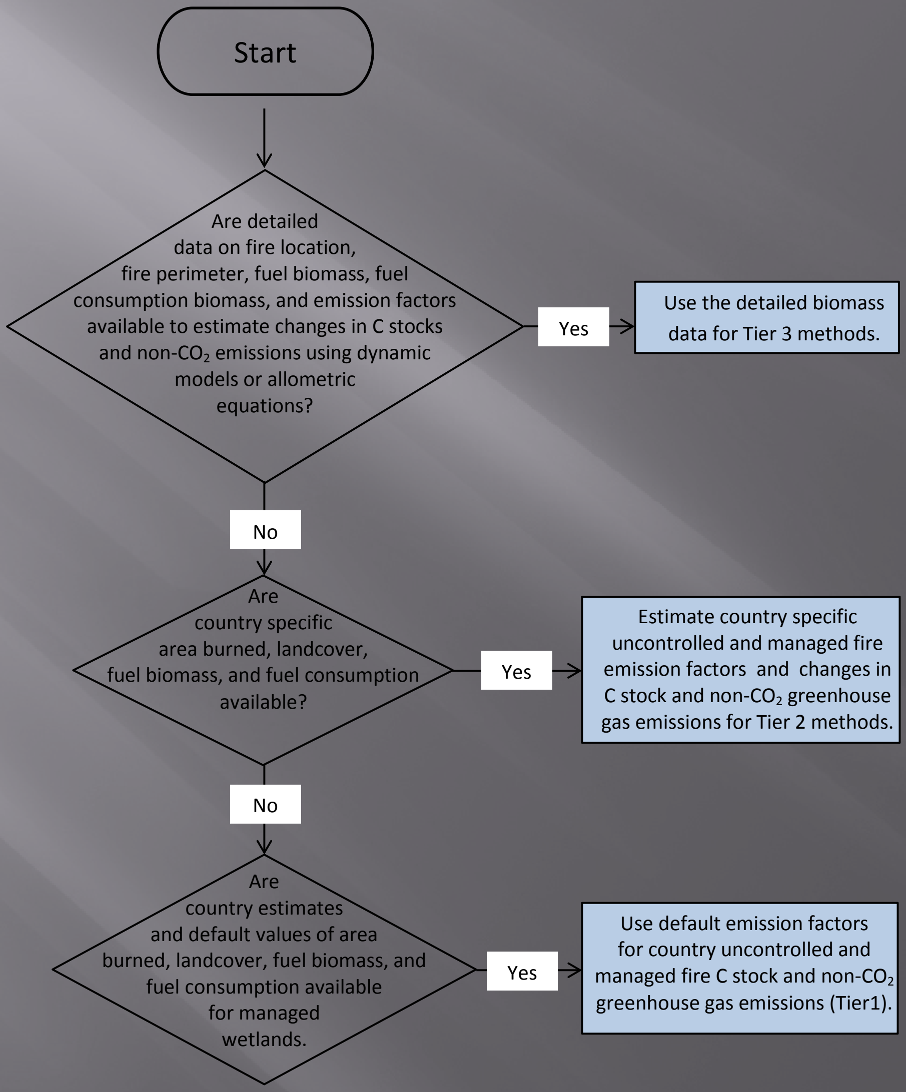


Default Emission Factors
2006 IPCC Guidelines for Natural Greenhouse Gas Inventories

TABLE 2.4
FUEL (DEAD ORGANIC MATTER PLUS LIVE BIOMASS) BIOMASS CONSUMPTION VALUES (TONNES DRY MATTER HA^{-1}) FOR FIRES IN A RANGE OF VEGETATION TYPES
(To be used in Equation 2.27 , to estimate the product of quantities ' $M_B \cdot C_f$ ' , i.e., an absolute amount)

Vegetation type	Subcategory	Mean	SE	References
Primary tropical forest (slash and burn)	Primary tropical forest	83.9	25.8	7, 15, 66, 3, 16, 17, 45
	Primary open tropical forest	163.6	52.1	21,
	Primary tropical moist forest	160.4	11.8	37, 73
	Primary tropical dry forest	-	-	66
All primary tropical forests		**119.6**	**50.7**	
Secondary tropical forest (slash and burn)	Young secondary tropical forest (3-5 yrs)	8.1	-	61
	Intermediate secondary tropical forest (6-10 yrs)	41.1	27.4	61, 35
	Advanced secondary tropical forest (14-17 yrs)	46.4	8.0	61, 73
All secondary tropical forests		**42.2**	**23.6**	66, 30
All Tertiary tropical forest		**54.1**	-	66, 30
Boreal forest	Wildfire (general)	52.8	48.4	2, 33, 66
	Crown fire	25.1	7.9	11, 43, 66, 41, 63, 64
	Surface fire	21.6	25.1	43, 69, 66, 63, 64, 1
	Post logging slash burn	69.6	44.8	49, 40, 66, 18
	Land clearing fire	87.5	35.0	10, 67
All boreal forest		**41.0**	**36.5**	43, 45, 69, 47
Eucalypt forests	Wildfire	53.0	53.6	66, 32, 9
	Prescribed fire – (surface)	16.0	13.7	66, 72, 54, 60, 9
	Post logging slash burn	168.4	168.8	25, 58, 46
	Felled, wood removed, and burned (land-clearing fire)	132.6	-	62, 9
All Eucalypt forests		**69.4**	**100.8**	
Other temperate forests	Wildfire	19.8	6.3	32, 66
	Post logging slash burn	77.5	65.0	55, 19, 14, 27, 66
	Felled and burned (land-clearing fire)	48.4	62.7	53, 24, 71
All "other" temperate forests		**50.4**	**53.7**	43, 56

Proposed Decision Tree to Estimate Carbon Stocks and Non-CO_2 Greenhouse Gas Emissions for Uncontrolled and Managed Fires in Managed Wetlands.



Challenges for the
The Intergovernmental Panel on Climate Change (IPCC)
Fifth Assessment

- Managed vs. Unmanaged Wetlands – Defining Managed Wetlands
- Peatlands vs. Histosols – Defining Organic Soils
- Stock vs. Flux – Measurement Methods
- Location and Estimate of Area Burned in Prescribed and Wild Fires
    - Remote Sensing and Ground-Based Information
- Vegetation Classification and Fuel Loading
    - Spatial Vegetation Landcover
    - Fuel Loading Methods and Classifications
- Fuel Consumption
    - Above-Ground
    - Below-Ground – Organic Soil Bulk Density and Consumption Depth
    - Spatial and Temporal
- Emission Factors
    - Available Data

Questions

Pains Bay Fire – Low Pocossin Backfire