

Measuring Emission Factors from Open Fires and Detonations

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Background

- Open area emission sources are increasingly recognized for their impacts on pollutant exposure and air quality attainment
- Sources include
 - Wildfires
 - Prescribed forest and agricultural fires
 - Demilitarization operations
 - Oil and gas field emissions
 - Chemical industry emissions
 - Landfill fires
 - Accidents (e.g., train car derailments)



41% of the PM_{2.5} emissions in the USA are attributed to wildland and agricultural fires (2011 EPA National Emission Inventory).

Examples of Open Emission Sources

**Military Fast
Cook Off Tests**



**Agricultural and Forest
Burning**



**Dump Fires, Burn
Pits**



**Demilitarization
Detonations**



At-Sea Oil Burns



**Demilitarization
Propellant Burns**



Train Accidents



Use of Emission Data

- Air operating permits
- Exposure/environmental risk assessment
- Technology comparisons



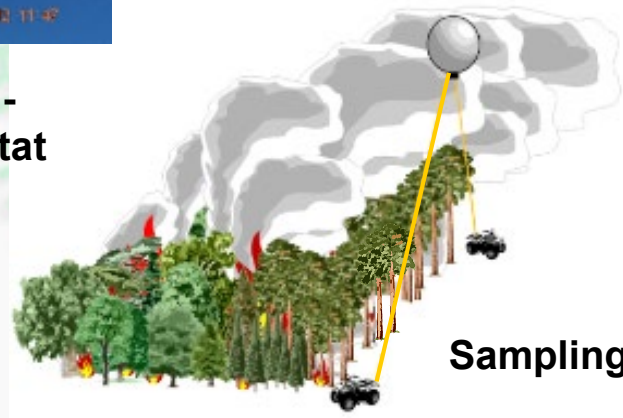
Unmanned Aerostat Carrying “Flyer”



5 m diameter, helium-filled, tethered aerostat



The EPA “Flyer”: An unmanned, telemetry-controlled sampling system



Sampling a prescribed fire

Instrumentation/Measurements

Analyte	Instrument/Method	Frequency
CO ₂	NDIR ^a	Continuous
CO	Electrochemical cell	Continuous
PM _{2.5}	Impactor/Teflon filter/gravimetric	Batch
PM by size	DustTrak	Continuous
Metals	Filter, XRF/ICP	Batch
Volatile Organic Compounds (VOCs)	SUMMA Canister, Tenax sorbent, CarboTrap	Batch
Polycyclic Aromatic Hydrocarbons (PAHs)	Quartz filter PUF/XAD-2/PUF	Batch
Black carbon	Micro Aethalometer, AE51, and MA350	Continuous
Elemental carbon/ Organic Carbon/Total Carbon	Quartz filter	Batch
Carbonyls	DNPH cartridge	Batch
Carbohydrates	Teflon filter	Batch
NO, NH ₃ , SO ₂ , NO ₂	Electrochemical cell	Continuous
Energetics	Quartz filter, HPLC	Batch
Dioxins (PCDD/PCDF)	Quartz filter, PUF, HRGC-HRMS	Batch
HCl	Na ₂ CO ₃ Treated filter, IC	Batch

Sampling Open Fires

Prescribed fires on DoD lands:

- Reduce ground fuels and reduce wildfire hazard
- Maintain the natural ecosystem
- Manage the land for training purposes

Demilitarization operations

- Open Burning (OB) of propellant
- Open Detonation (OD)
- Static Firing (SF) of rocket motors

Reduce storage risk and safely dispose of obsolete and unneeded ordnance



Sampling Emissions from Detonation Plumes



Tethers/winches
downwind



Aerostat/Flyer

Video of Aerostat/Flyer



ENTAL PROTECTI

Sampling Prescribed Burns with the Aerostat/Flyer



Limits on Aerostat/Flyer Method

Tethered aerostat/Flyer sampling has worked well in measuring open fire emission factors, but has constraints:

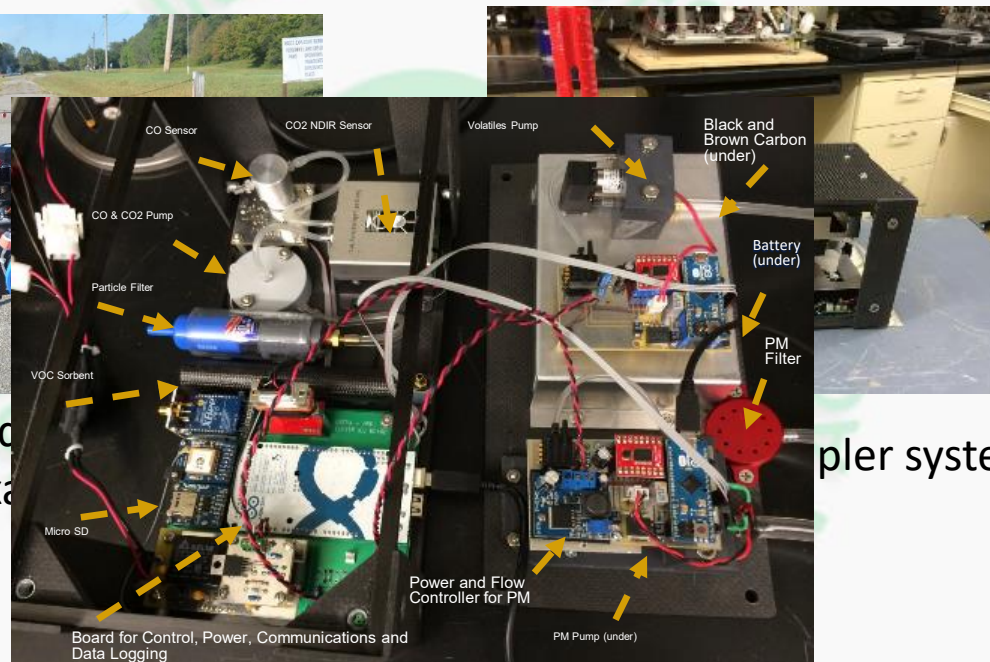
- Maneuverability
 - Tethers (trees, power lines)
 - Need 1 or 2 winch-mounted ATVs
 - Limited 3D range (wind shifts, plume drift)
 - Terrain and boundary limits
- Resource requirements
 - Large team
 - Large equipment (and helium)
 - Cost (personnel, helium, logistics)



An Unmanned Aerial System (UAS, aka “drone”) carrying the EPA/ORD “Kolibri” sampler

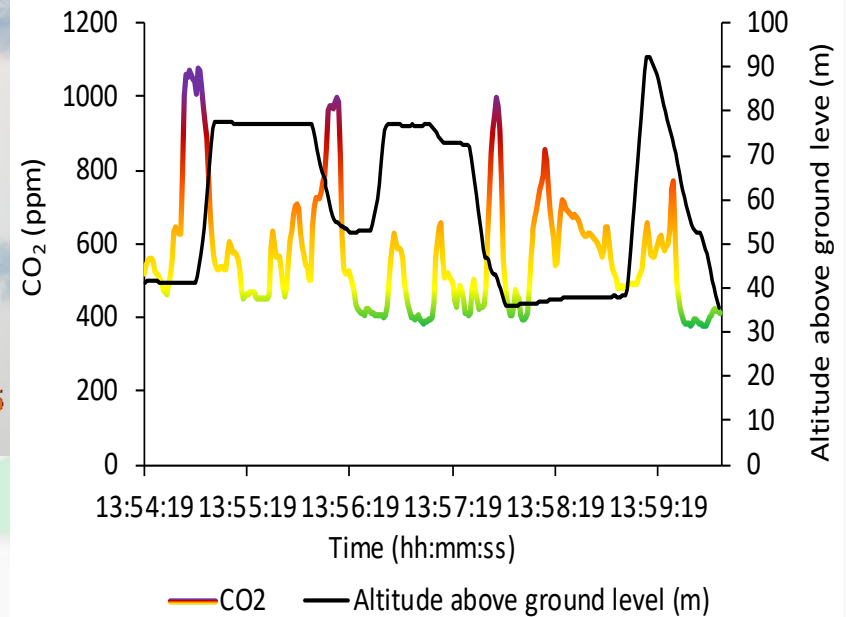


NASA-owned
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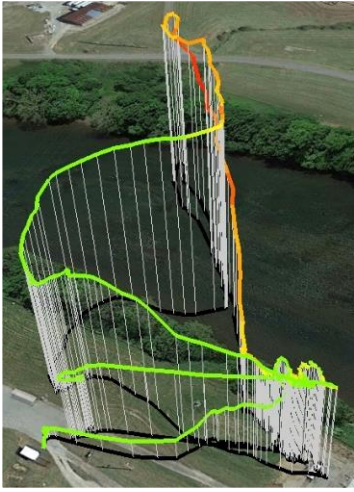


pler system

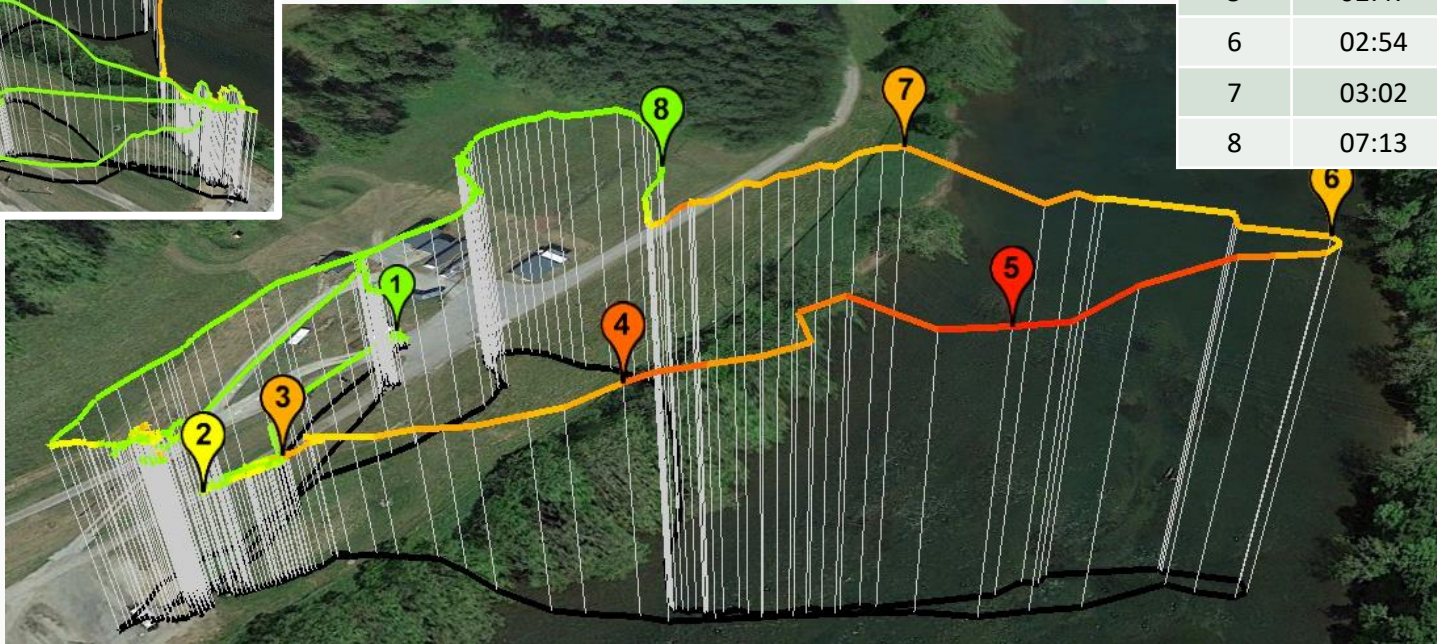
Prescribed Forest Burn Sampling



Path of NASA's UAS/Kolibri During Open Burn Emission Sampling



UAS path, color-coded with CO2 concentration
Higher CO2 concentration indicates plume presence

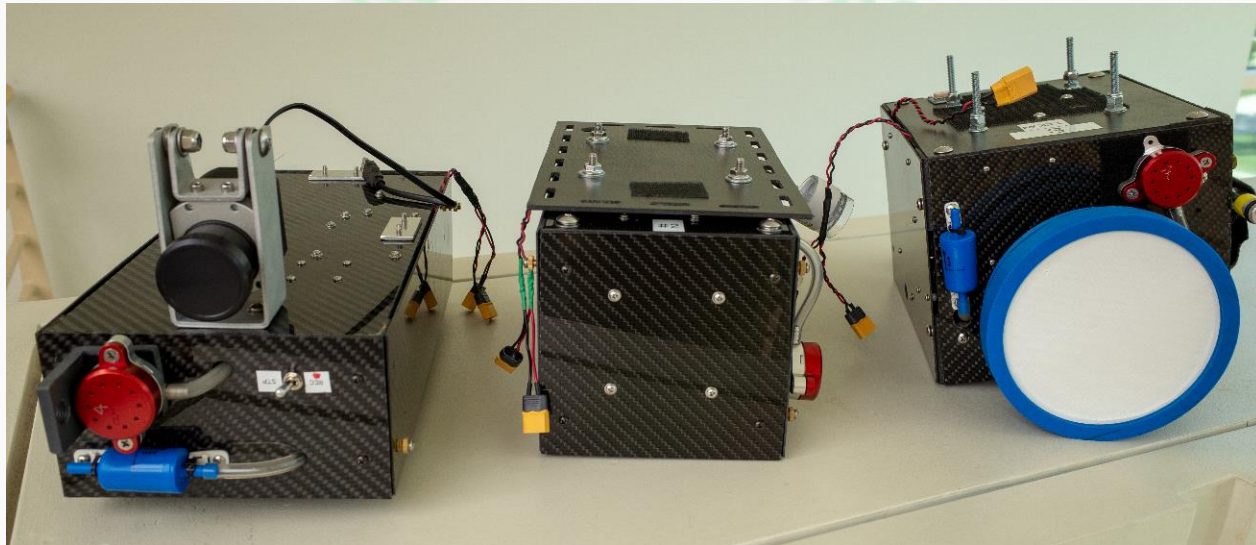


Mark [#]	Time [mm:ss]	Height [m]	CO2 [ppm]
1	00:00 (240)	524	431
2	00:49	542	1851
3	02:25	544	2831
4	02:39	561	3441
5	02:47	572	4085
6	02:54	583	2562
7	03:02	602	2678
8	07:13	586	436

UAS/Kolibri Flights



Multiple Versions of the Kolibri



Field Deployments of the Flyer and Kolibri Samplers

Source	Location	Year
Burning oil on water ¹	Deepwater Horizon, Gulf of Mexico	2010
Demilitarization burning/detonations ^{2, 5}	Tooele, UT	2010, 2011, 2012
Prescribed wildland fire ³	Camp Lejeune, NC	2011
Prescribed wildland fire ³	Fort Jackson, SC	2011
Prescribed wildland fire ³⁻⁴	Eglin Air Force Base, FL	2011, 2012
Demilitarization burning/detonations	Saskatchewan, Canada	2013
Prescribed agricultural fires	Idaho, Washington	2013
Kerosene pool fire ⁸	Dahlgren, VA	2016
Municipal waste fire ⁷	Tooele, UT	2011
Timber slash pile ⁶	Grand Ronde, OR	2015
Prescribed range burn	Manhattan, KS	Mar, Nov 2017
Prescribed wildland fire	Sycan Marsh, OR	2017
Prescribed wildland fire	Tall Timbers, FL	2017
Prescribed range burn	Tallgrass Prairie, KS	2017
Oil burns on water	Hanover, NH	May 2018
Oil burns on water ⁹	Aberdeen, MD	2016
Oil burns on water	Hanover, NH	Nov 2018
Range detonations ¹⁰	Anchorage, AK	2014
Demilitarization propellant burns	Radford, VA	2016
Demilitarization propellant burns ¹¹	McAlester, OK	2016, 2017
Natural gas boiler, downwind	Midland, MI	2018
Prescribed wildland fire	Tall Timbers, FL	2018

Conclusions

- Two aerial emission sampling platforms have been developed
- A comprehensive array of emissions can be sampled
- 20 field campaigns since 2010 have proven these technologies
- The Flyer and Kolibri are obtaining data never before gathered
 - Safely, for personnel and equipment
 - Representative sampling
- These data give more accuracy and confidence in risk and exposure assessments



Acknowledgements

- EPA's Office of Research and Development and Region 7
- DoD Strategic Environmental Research and Development Program (SERDP)
- Joint Munitions Command, PEO Ammunition
- Department of National Defence / Government of Canada
- NASA Ames
- Desert Research Institute
- Tall Timbers Research Station
- Tallgrass Prairie Nature Preserve
- Konza Prairie Biological Station
- U.S. Army Ammunition Depots