Developments in Emission Measurements Using Lightweight Sensors and Samplers

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Abstract

Lightweight emission measurement systems making use of miniaturized sensors and samplers have been developed for portable and aerial sampling of an array of pollutants.

Shoebox-sized systems called "Kolibri", weighing 3-5 kg, have been deployed on NASA-flown unmanned aerial systems (UASs, or "drones") to characterize plume emissions from open combustion sources. A larger instrument system (20+ kg) called the "Flyer" is lofted into pollutant streams using a tethered, helium-filled aerostat or balloon. These aerial systems have been used to determine emission factors from a variety of open burning sources including oil burns, waste pile burns, agricultural field burning, prescribed wildland fires, and open burning/open detonation of military ordnance:

Method

Two aerial sampling platforms have been developed to sample emissions from plumes of open burns.

An aerostat-lofted instrument package, named the "Flyer," was developed to sample multiple pollutant types. Two ATVs, each with an electric winch for the 1000 ft [305 m] tethers, to anchor and maneuver the helium-filled aerostat into the plumes. The Flyer includes an on-board computer, control software, and a wireless transmitter which allows the sampling to be controlled from the ground while incorporating CO_2-induced "triggers" that control multiple on/off switches for the samplers.

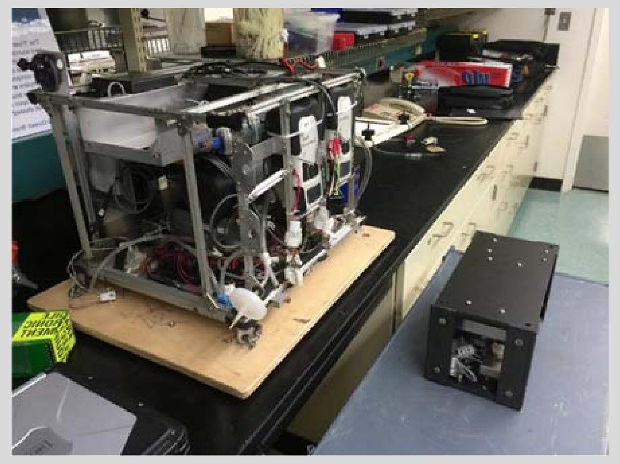
For sources that require greater flexibility in positioning and where shorter plume residence times are sufficient, a hexacopter unmanned aerial vehicle (UAV, or drone) -lofted sampler, named the "Kolibri", was developed using miniaturized sensors, high power density batteries, and carbon fiber framing. The Kolibri includes an on-board Teensy computer and a telemetry system for control and data transmittal software.

The Kolibri and Flyer use sensors to measure CO and CO_2 and miniature samplers for $PM_{2.5/10}$, PAHs, VOCs, SVOCs, carbonyls, metals, black/elemental/organic carbon (BC/EC/OC), inorganic halogens, and real time BC. New capabilities are being added including NOx sensors and a real time sampler for particle size distributions.

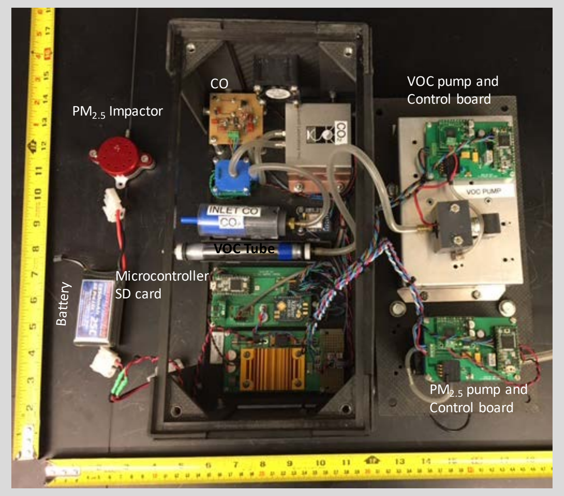
Aerostat (16-ft dia.).

The 46 lb [21 kg] sampling package called the "Flyer".

DJI Matrice M600 with large Kolibri.

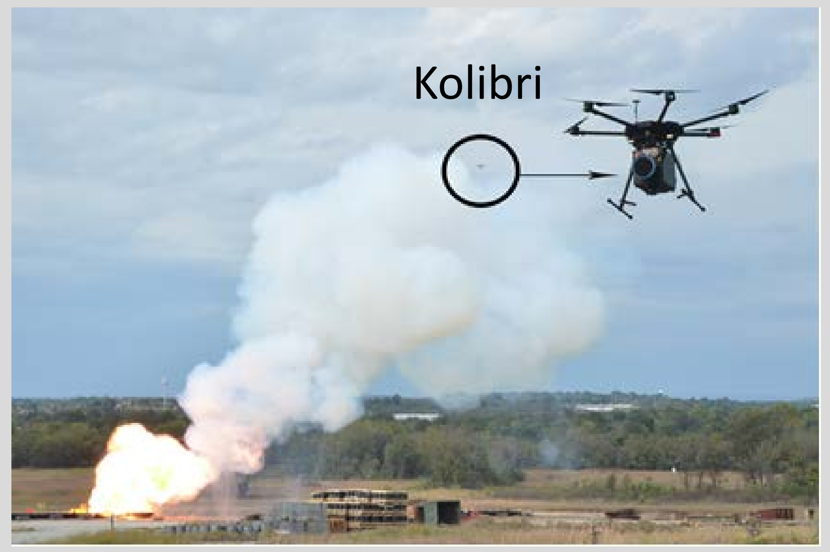


Size comparison of Flyer and Kolibri.



6-11 lb [3-5 kg] sampling package called the "Kolibri" (L) and its internals (R).

Flyer method.



Kolibri method.

Results

Sampling of prescribed prairie grass burns.

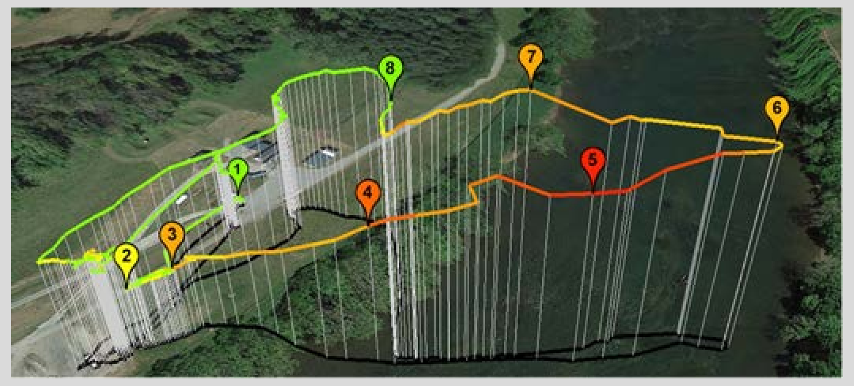
Sampling of prescribed forest burns.

Sampling of prescribed burning of timber slash piles

At-sea sampling of surface oil burning during Deepwater Horizon incident.

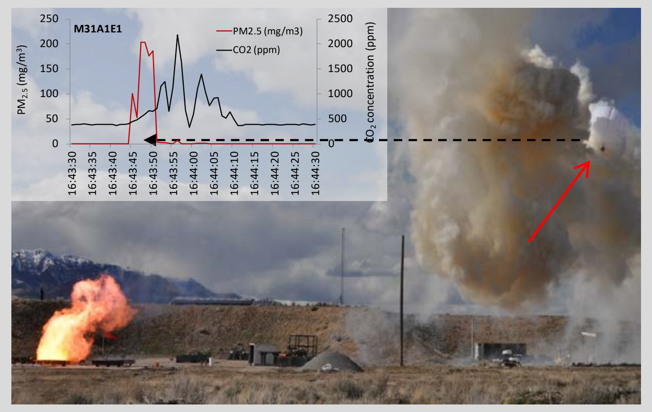
Prescribed agricultural burns.

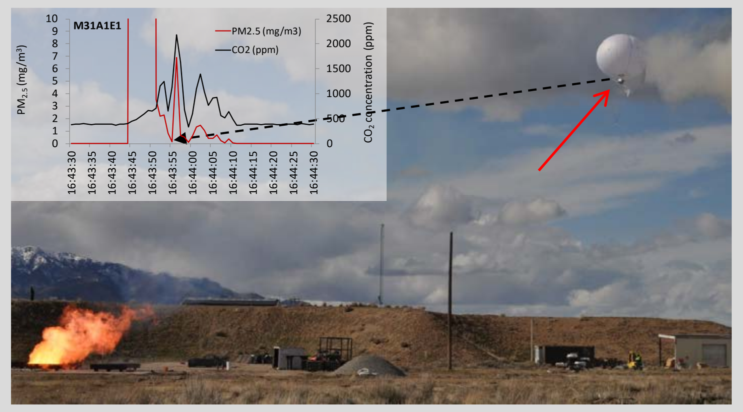
Sampling of waste pile burns.



Flight path of Kolibri and colored intensity of CO_2 from combustion plume. Path along the ground(black) projected by white lines.

Mark [#]	Time [mm:ss]	Height ASL [m]	CO_2 [ppm]
1	00:00	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





The Flyer successively measured plumes from OB (shown) and OD. Continuous $PM_{2.5}$ and CO_2 trace for M31A1E1 propellant burn with an initial smoky plume (left) and subsequent invisible plume (right).

Acknowledgments

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