

Fire Emission Measurements Using Lightweight Sensors and Samplers on Unmanned Aerial Systems

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Emission measurement systems making use of miniaturized sensors and samplers have been developed for portable sampling from aerial platforms. Small, shoebox-sized systems called “Kolibri”, weighing 3-4.5 kg, have been deployed on USGS- and NASA-flown unmanned aerial systems (UASs, or “drones”) to characterize plume emissions from open area combustion sources. A 5 m diameter, tethered, helium-filled aerostat (balloon) has been used to loft a larger instrument system (20+ kg) called the “Flyer” into combustion plumes. Both the Kolibri and Flyer use sensors to measure CO and CO₂ and miniature samplers for PM_{2.5/10}, PAHs, VOCs, SVOCs, carbonyls, black/elemental/organic carbon (BC/EC/OC), inorganic halogens, and real time BC. New capabilities are being added including IR cameras, NOx sensors, and a real time sampler for particle size distributions. Telemetry systems on both the Kolibri and Flyer transmit data to the ground crew to enable flight, battery, and sample monitoring. The Flyer has 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. The Kolibri has been successfully and safely deployed in five campaigns to determine emission factors from prescribed fires and open burning and detonation demilitarization processes.



The NASA UAS – a six rotor DJI Matrice M600 system with the ~ 4 kg EPA/ORD “Kolibri” sampler after being in a plume. Note the black filter.

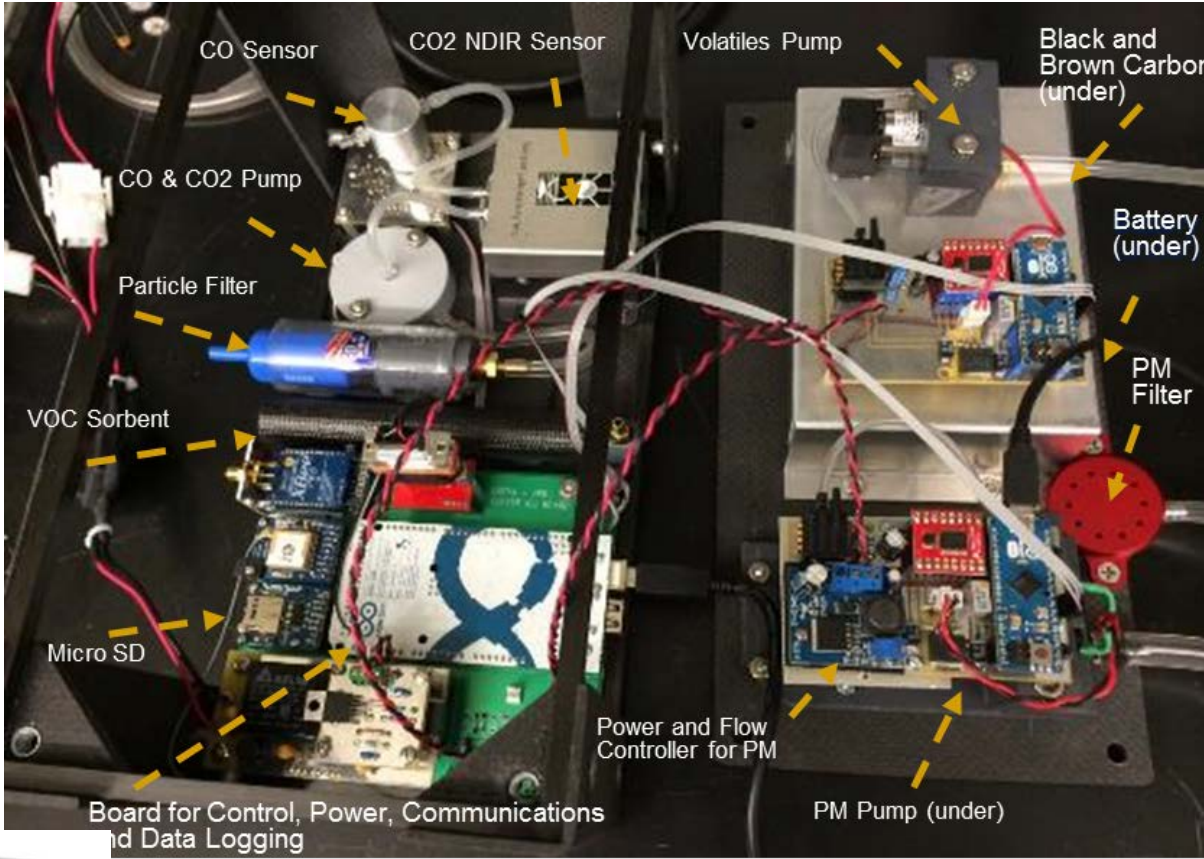
Target Analyte	Instrument	Time Resolution
CO ₂	NDIR sensor	Continuous
CO	Electrochemical cell sensor	Continuous
NO, NO ₂	Electrochemical cell Sensor	Continuous
Black/brown carbon	MA200 (Aethlabs)	Continuous
PM by size	DustTrak DRX (TSI)	Continuous
Temperature	IR Camera (Micro-Epsilon)	Continuous
PM _{2.5/10} /Composition	Teflon/Quartz Filter/XRF	Batch
Polycyclic aromatic hydrocarbons	PUF/XAD/PUF	Batch
PCDD/PCDF	PUF/Quartz Filter	Batch
Volatile organic compounds	Summa can/sorbent tube	Batch
Carbonyls	dNPH cartridge	Batch
Energetics	Quartz filter	Batch
HCl, O ₃ , SO ₂ , Cr(VI)	Sorbent tubes	Batch



The EPA/ORD Aerostat/“Flyer” system. The 5m diameter, helium-filled aerostat lofts the ~22 kg Flyer into plumes. The sampling system is controlled by CO₂ concentration triggers and by the ground operator and a data telemetry system.



The shoebox-sized Kolibri



The Kolibri internals



IR camera



The Flyer

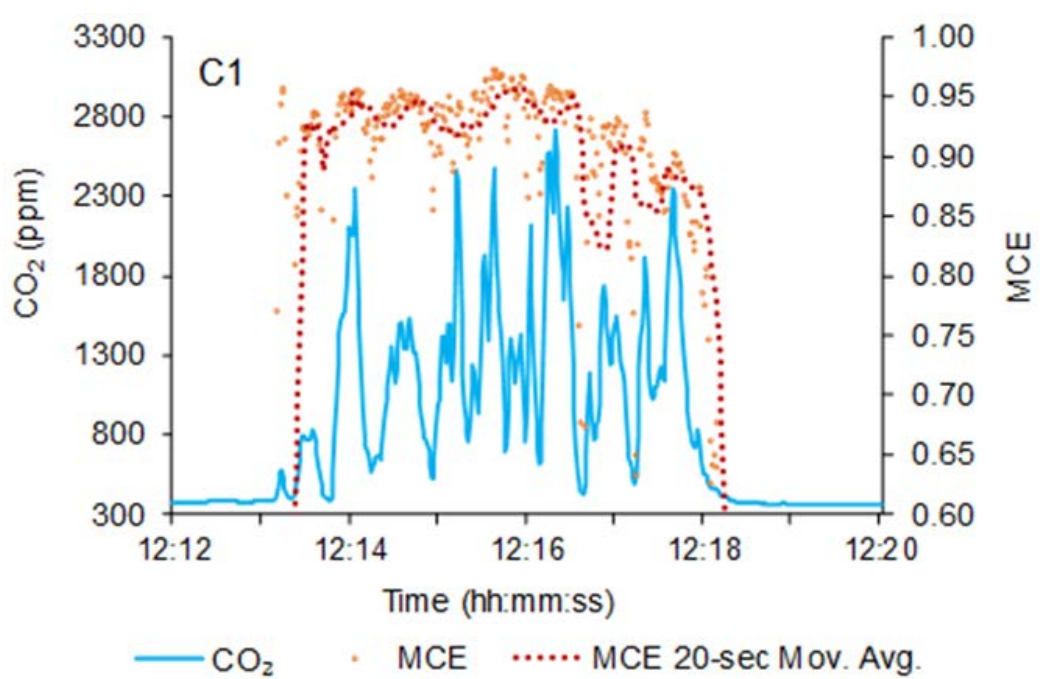
Applications of Aerial Sampling



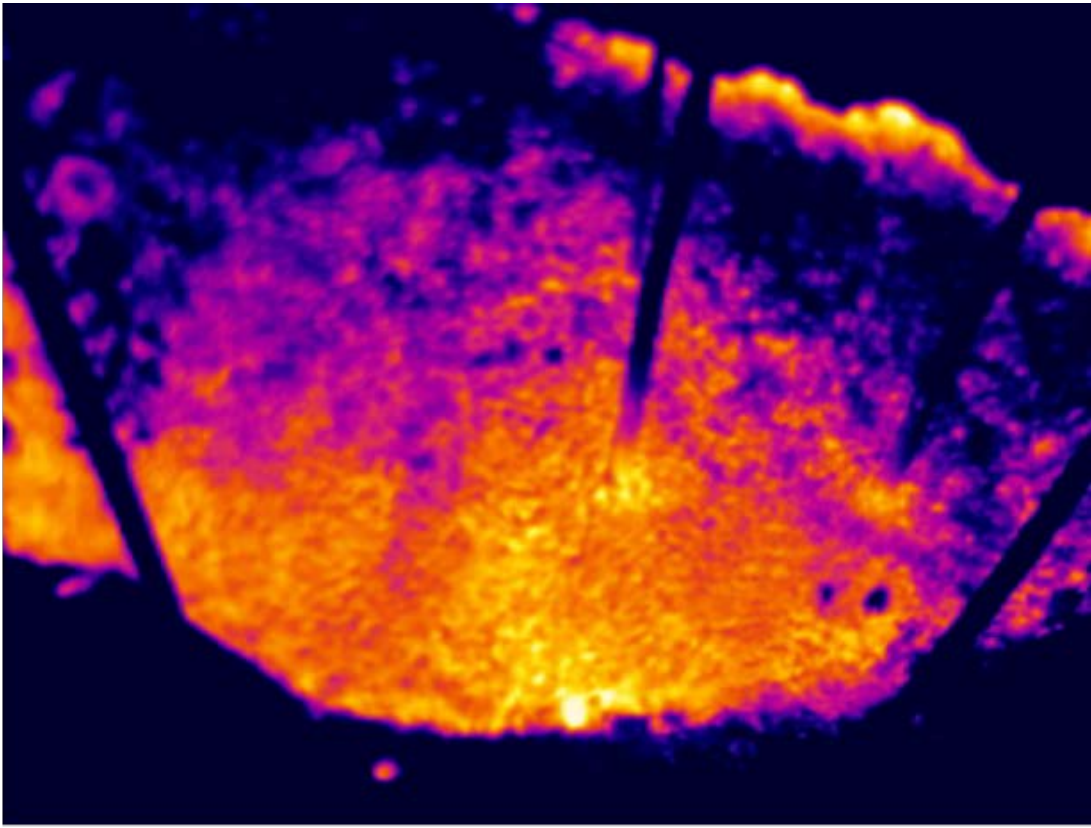
UAS sampling of open burning of propellant



UAS sampling of prescribed forest burns



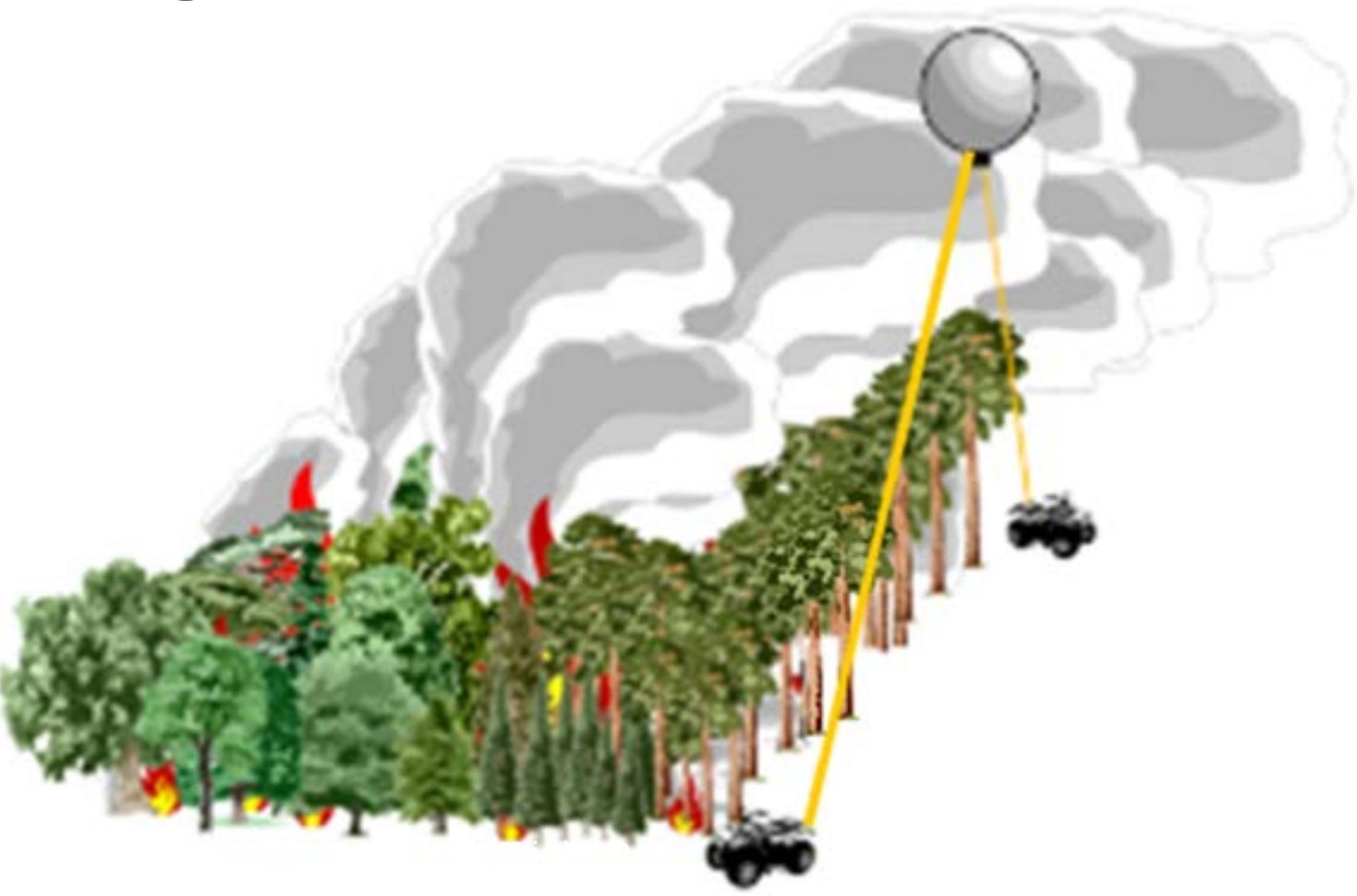
CO₂ concentrations and modified combustion efficiency for a UAS flight of a prescribed forest burn at Tall Timbers Research Station, Florida.



IR image from UAS sampling of prescribed forest burns at Tall Timbers Research Station, Florida



Forest Burn, NC State



Schematic of Flyer UAS sampling of prescribed forest burns



Aerostat/Flyer sampling from wheat stubble burns, Oregon State.



“Wildfire” SC State



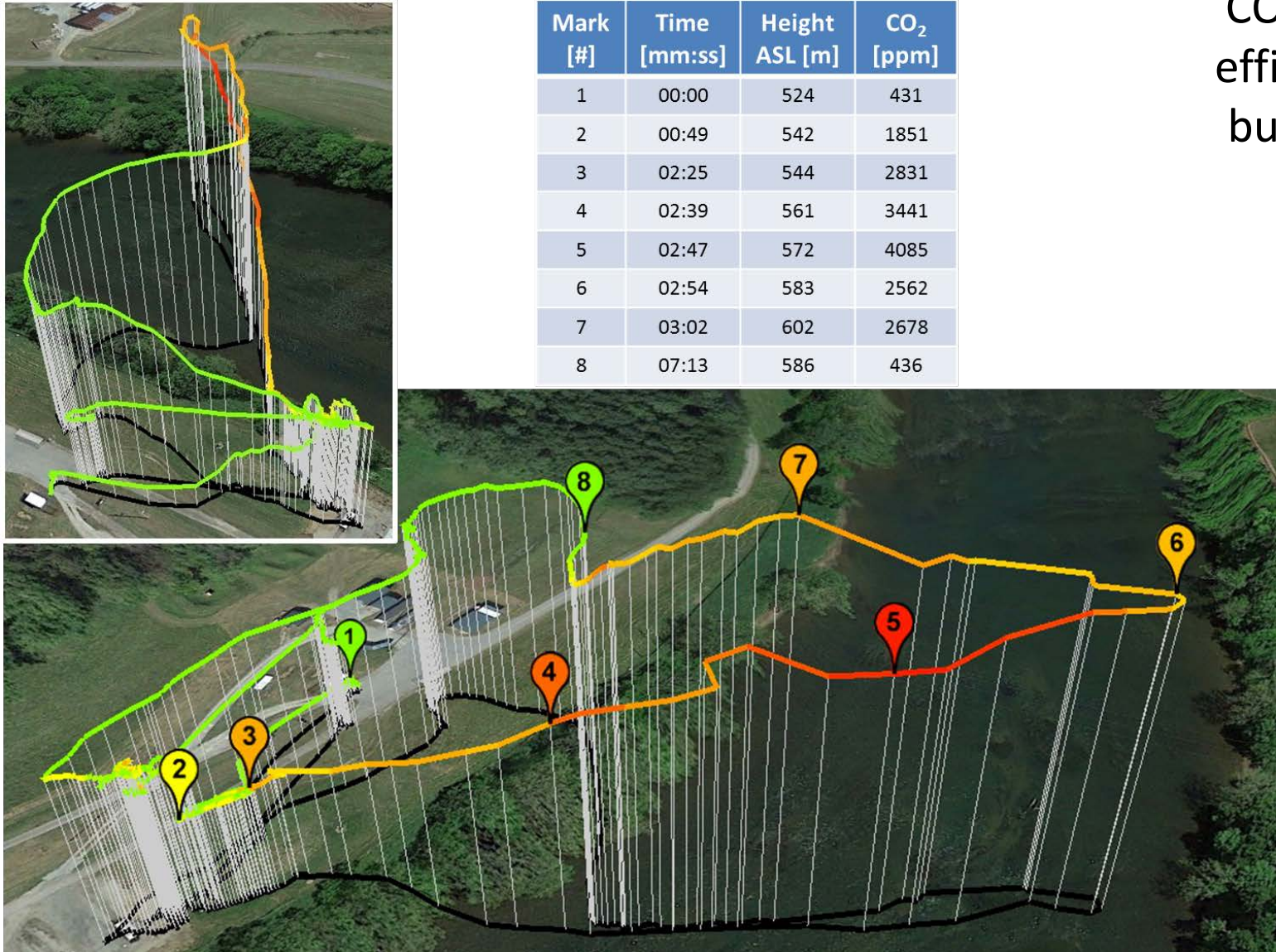
Open Detonation sampling in Utah



Wheat stubble burn sampling in Oregon State.



Wheat field sampling in Washington State.



UAS sampling of US Army Open Burning of obsolete propellant. The 3D image shows the path of the UAS and the color indicates the CO₂ concentration as an indicator of being in the plume.

Acknowledgments

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Representative Publications

