The Role of Unmanned Aerial Systems/Sensors in Air Quality Research

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Purpose of Presentation

- To describe the application of new miniature sensors and aerial sampling technology to better quantify emissions from hard-to-sample, open area sources.
- To explain the status of the technology
- To highlight recent applications

Examples of Open Area Emission Sources

- Prescribed forest and agricultural burns
- Wildfires
- Landfills
- Lagoons
- Industrial complexes
- Agricultural operations
- Oil and gas fields
- Disposal of obsolete military ordnance

Emission Sampling

- Open area sampling, vs. stack sampling, is becoming more important as
  - Industrial point sources are now more well-characterized
  - Open area sources are recognized for their importance to air shed pollution management
  - Global climate impacts from these source are of growing concern

Sampling Method Considerations

- What are the target analytes, their concentrations, and their temporal history?
  - What sampler type is needed?
  - How much sample volume is needed to exceed detection limits?
  - How quickly must the sampler respond to changes in concentration?
- What are the emission plume characteristics: height, breadth, duration, accessibility?
  - Is an aerial sampler needed?
  - Is the plume discrete or broad?
  - Will the terrain, biota, and structures allow access?
- What are the safety considerations, equipment and personnel?

Aerial Sampler

For plumes at elevation, we've developed an aerostat-lofted sampling instrument – the "Flyer"

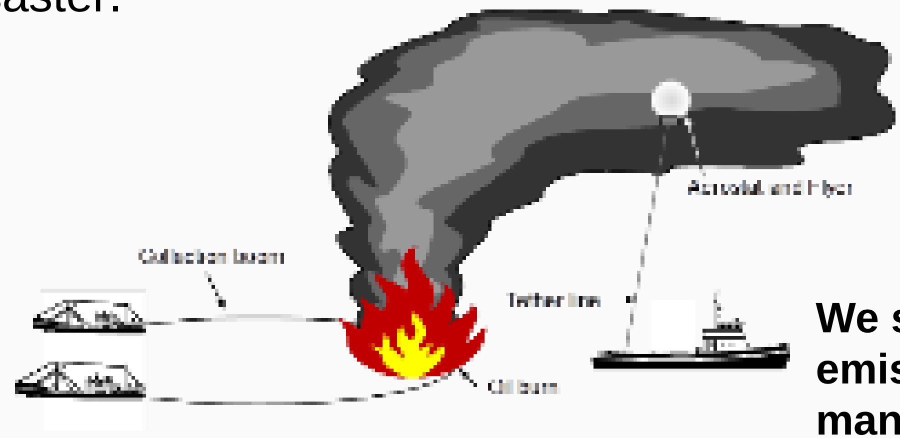
- Total weight ~ 21 kg (46 lb)
- Onboard computer with data transmission
- User-set CO_2 triggering of samplers
- GPS, CO_2, CO
- Semi-Volatile Organic Compounds (SVOCs)
- Volatile Organic Compounds (VOCs)
- Black carbon (BC)
- Brown carbon
- PM by filter ($PM_{2.5}$, PM_{10})
- Continuous $PM_{2.5}$, PM_{10}
- 3D-anemometer

The "Flyer"

Examples of Open Area Emission Sampling with the Flyer

Sampling the plumes from the in situ oil burns in the Gulf of Mexico during the BP Deepwater Horizon disaster.

The surface oil was gathered by two trawlers towing a floating boom. It was then ignited.



We sampled the emissions by maneuvering the Flyer into the plume.

The marginal combustion and the presence of Cl from (at least) the seawater raised the question of whether formation of chlorinated dioxins and furans was possible.

Examples of Open Area Emission Sampling with the Flyer

Sampling prescribed fires: forests and agricultural fields.

Use of two tethers attached to electric winches and mounted on two ATVs allows some optimization of the aerostat/Flyer position in the plume.

Examples of Open Area Emission Sampling with the Flyer

- **Obsolete military ordnance is often disposed via open burning and open detonation**






- 10-20 seconds in the plume
- High volume sampling rate
- Trigger samplers with CO2 conc.
- “spin up” sampling pumps prior to the plume

Limits on Aerostat/Flyer Method

Tethered aerostat sampling has worked well, but has constraints:

- Maneuverability.
  - Tethers (trees, power lines)
  - ATVs
  - Limited 3D range (wind shifts, plume drift)
  - Terrain and boundary limits
- Resource requirements.
  - Large team
  - Large equipment (and helium) Cost
- Response time is weeks+

New Sensor and UAS Technologies

The confluence of developments in miniaturized sensor technology and unmanned aircraft systems (UASs) has promise for enabling new methods of open area emission sampling.

Sensors and Small Samplers

- Electrochemical
- Metal oxide
- Small IR
- Filter-based
- optical

UASs

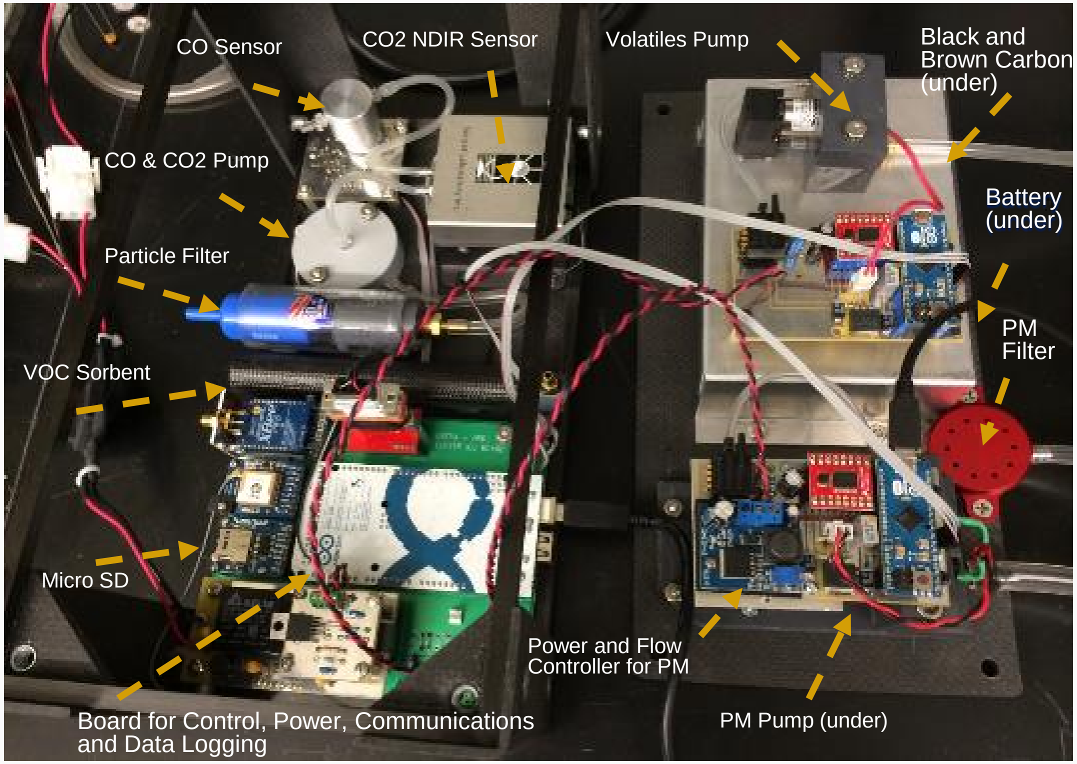
- Advances in GPS, carbon fiber, computer, and battery technologies
- Varied in size and capability; some as small as a dollar bill.
- Operator controlled or fly programmed paths
- They have auto-return, boundary, and auto-land features
- Personnel are safely at a distance
- Recent designs can carry payloads of 5 kg for 15-20 minutes.
- They are portable (fold up) and fast to deploy
- They do not have a disturbance footprint
- Require only two people
- Costs range from $50 - $20K

Development of a Sensor/Small Sampler Platforms

The "Kolibri"

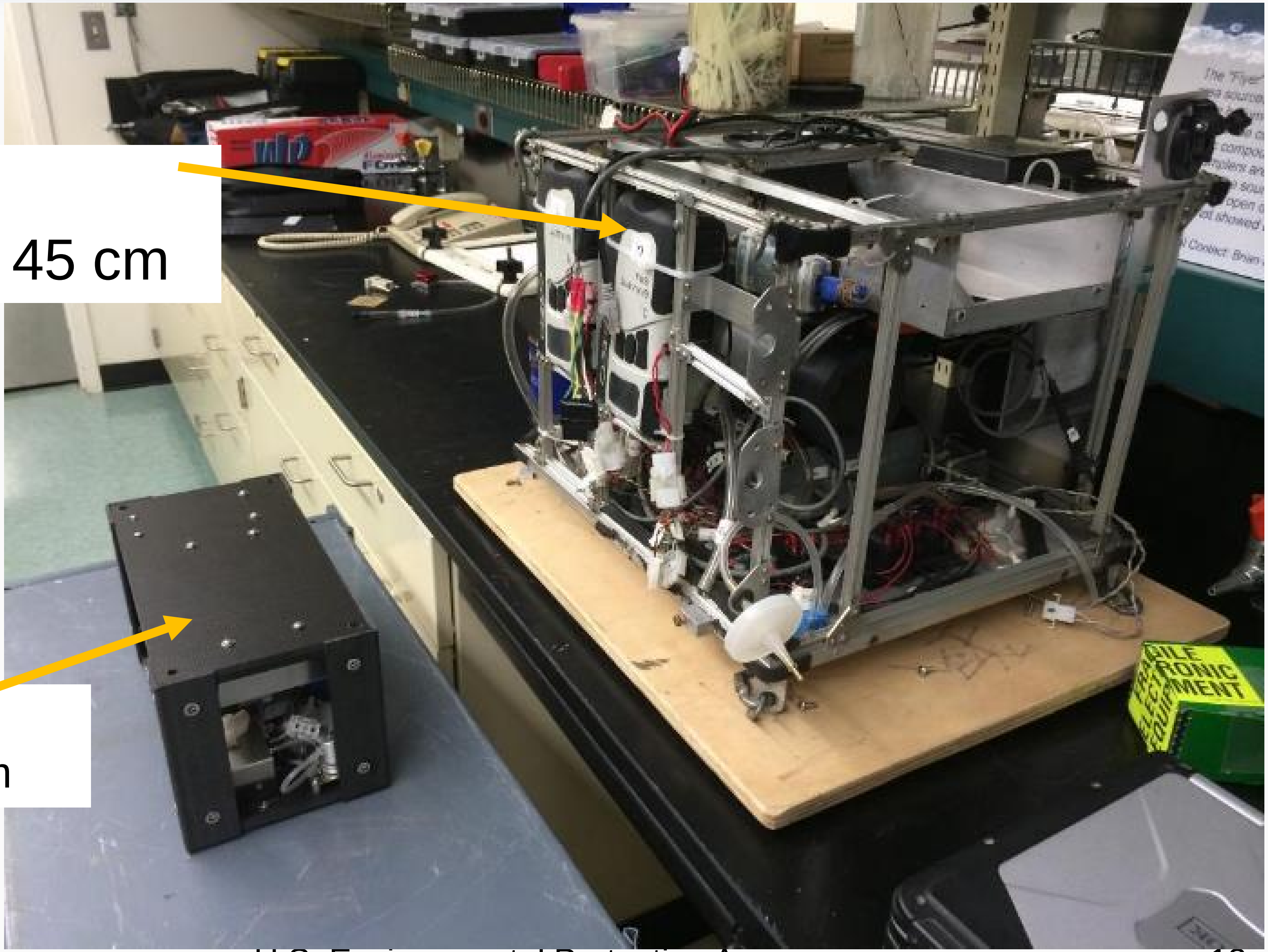
The Kolibri is 3.56 kg and measures (for now)

- CO2,
- CO,
- PM2.5 (& metals),
- Volatile organics
- Black Carbon,
- Brown Carbon.



Future developments:
•Semi-volatile sampler
•S, N, HC sensors
•Optical PM sensor

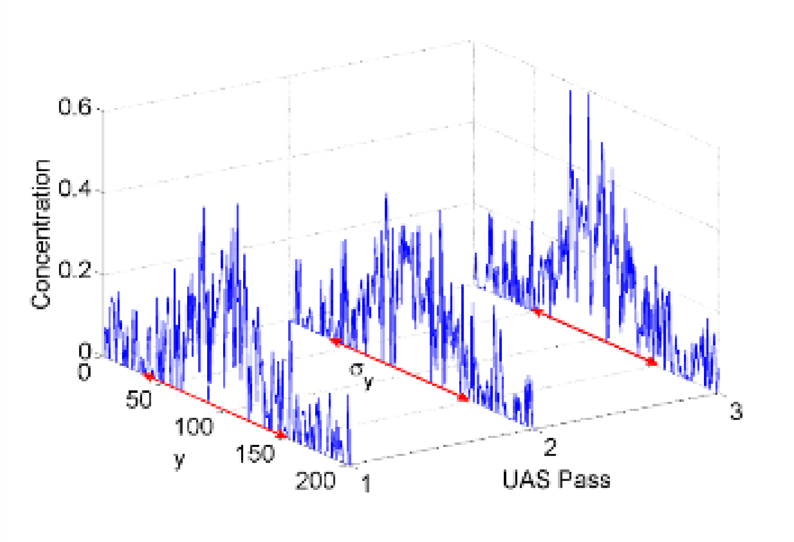
Kolibri vs. Flyer



>21kg,
55 x 50 x 45 cm

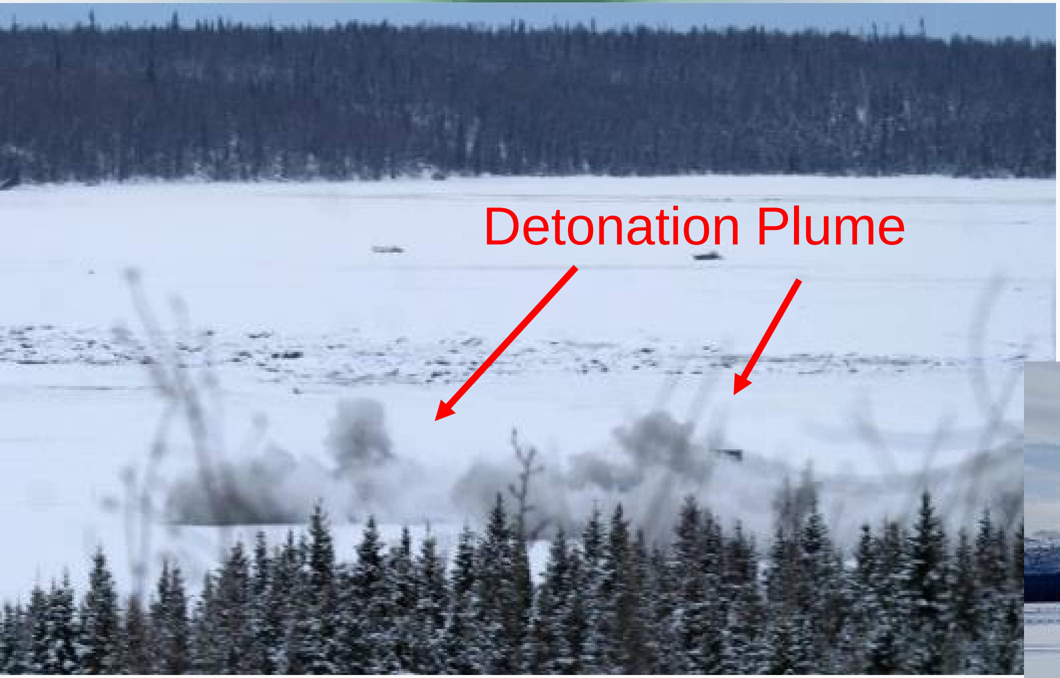
3.56 kg,
15 x 15 x 30 cm

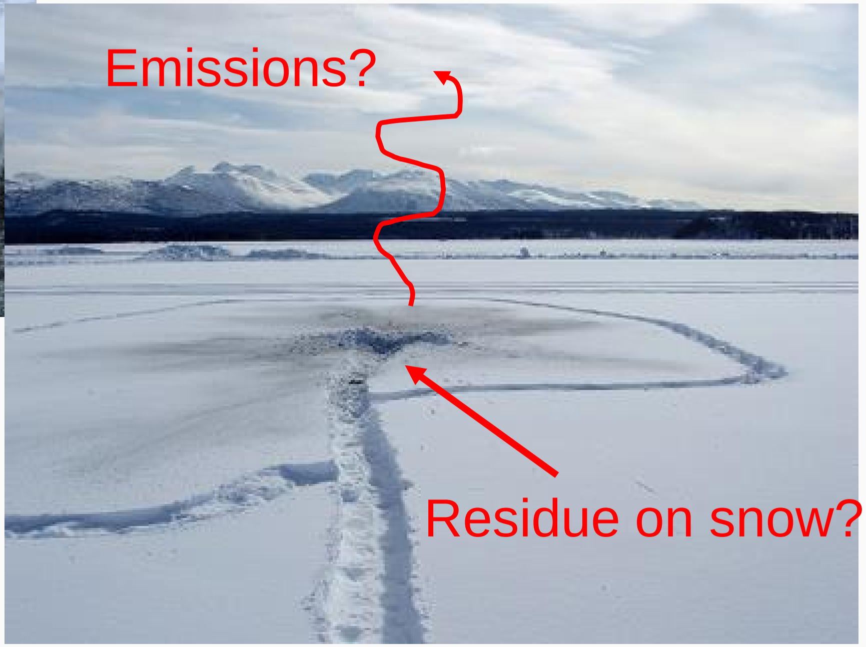
Application: Plume Quantification by UAS



Multiple passes of the UAS through the plume determines concentration profile and dispersion coefficients; allows calculation of source strength, S.

Application of the Kolibri/UAS: Detonations in Alaska



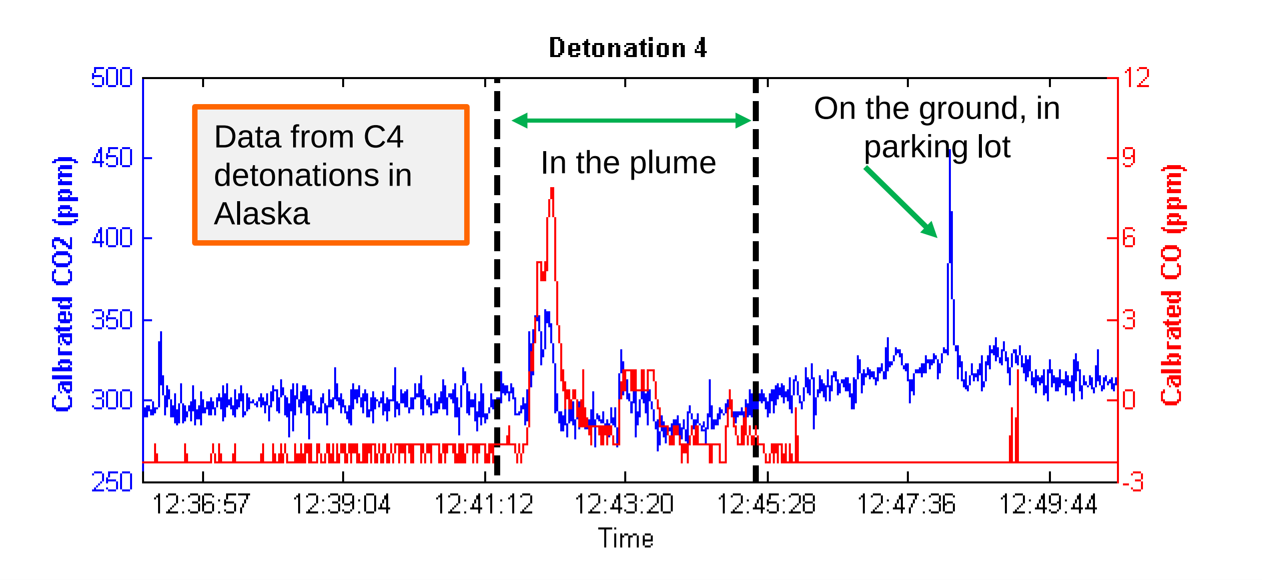


What are the residues from low-order (incomplete) detonations?

Development of lightweight sensor packages for aerial measurements

First flight in Anchorage, AK, Feb. 11, 2015 with Univ. AK-Fairbanks hexacopter on U.S. Army-sponsored project.

Gas sensor data from the plume:



UAS Flight in AK with EPA Sensor

Advantages: Aerial Systems and Sensors

- Significant safety advantage due to personnel set back distance
- Small “footprint” reduces response time to 1 day
- Decreases personnel from 6 to 2 (aerostat sampling)
- Mobility allows for more efficient source sampling
- Increases ability to characterize difficult sources
- Significantly reduces cost of field sampling by improving
- Complementary to fenceline, stack, and mobile source methods

Publications on Aerial Sampling

Environ. Sci. Technol. 2010, 44, 9431–9437

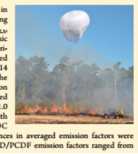
Aerostat Sampling of PCDD/PCDF Emissions from the Gulf Oil Spill In Situ Burns

JOHANNA AURELL AND BRIAN K. GULLETT

Environmental Science & Technology — Article

Emission Factors from Aerial and Ground Measurements of Field and Laboratory Forest Burns in the Southeastern U.S.: $PM_{2.5}$, Black and Brown Carbon, VOC, and PCDD/PCDF

Johanna Aurell and Brian K. Gullett*



Chemosphere 85 (2011) 806–811

Aerostat-lofted instrument and sampling method for determination of emissions from open area sources

Johanna Aurell, Brian K. Gullett, Christopher Pressley, Dennis G. Tabor, Robert D. Gribble

Journal of Hazardous Materials 284 (2015) 108–120

Aerostat-based sampling of emissions from open burning and open detonation of military ordnance

Johanna Aurell, Brian K. Gullett, Dennis Tabor, Ryan K. Williams, William Mitchell, Michael R. Kemme

Environmental Science & Technology — Article

Emissions from Open Burning of Simulated Military Waste from Forward Operating Bases

Johanna Aurell, Brian K. Gullett, and Dirk Yamamoto

Thank you!