UAS sensor package for environmental monitoring and air quality studies (WASPP-Whole Air Sampling Pilotless Platform)

Eric Apel NCAR
Elizabeth Asher NOAA
Alan Hills NCAR
Air quality on the Front Range is a problem

Fires impact air quality

Other pollution sources coupled to Front Range meteorological conditions impact air quality

2022 - EPA designates northern Front Range as a severe violator of ozone standards

Yes – this air can be polluted. Our main pollutant – Ozone – is an invisible gas and is often highest on clear and sunny summer days.
Air quality studies and air quality forecasts?
Why do we care?

Health Impacts of Ozone and PM2.5

In 2016, 91% of the world population was living in places where the WHO air quality guidelines levels were not met. Air pollution was estimated to cause 4.2 million premature deaths worldwide per year in 2016; People living in low- and middle-income countries disproportionately experience the burden of outdoor air pollution.

THE WORLD BANK
WASHINGTON, DC September 8, 2016—Air pollution has emerged as the deadliest form of pollution and the fourth leading risk factor for premature deaths worldwide. Those deaths cost the global economy about US$225 billion in lost labor income in 2013, a new study finds, pointing toward the economic burden of air pollution.

Energy Policy
Volume 90, March 2016, Pages 202-211

Air pollution emissions and damages from energy production in the U.S.: 2002–2011
Pauline Jaramillo A, R. R., Nicholas Z. Muller a, R.
View more

Health Costs ~Billions $
Air pollution/Ozone chemistry – some basics

VOCs = Volatile Organic Compounds
- There are 100s in the air and they come from cars, fracking, trees, fires

NOx = NO + NO2 from cars, industry, fires

VOCs (primary pollutants)
Fewer emissions does not always mean less ozone. The balance of NOx and VOCs determines how much ozone is produced.
Air pollution/Ozone chemistry studies

- Studies are conducted to determine the primary factors that cause the air pollution
- This information can be used to determine mitigation strategies

  *Mitigation Strategies for Primary Pollutants are clear: Reduced Emissions = Reduced concentrations*

  *Mitigation Strategies for Secondary Pollutants (e.g., ozone) are much more complex:*
  - *The chemical processes producing Secondary Pollutants are non-linear*

- Models are developed using emission inventories, meteorology and chemistry
Mitigation Strategies

Non-linear chemistry at work to form the secondary pollutant - ozone

Ozone Production can be determined/controlled/limited by the availability of either VOCs or NOx

⇒ In the case that ozone production is limited by how much VOCs are there, Reducing VOC emissions most effective for reducing ozone*

* non-local transport of pollution could counteract local mitigation strategies!
Why UAS sampling for air quality studies?

- Air quality studies come in different flavors
  - surface site measurements
  - aircraft-based measurements

- Region of the troposphere that is less accessible (0-1000 ft) is geographically less well studied – mostly the following have been used
  - Balloon-based measurements
  - Tower-based measurements

- Atmospheric boundary layer height is temporally and geographically variable
Niche for monitoring air quality by UAS?

UAS measurements for air quality studies:

- Multi-rotor UAVs can repeatedly and map out spatial gradients in the vertical and horizontal
- Pollution source attribution
- Air quality forecasts
WASPP collects whole air samples and meteorological data

- Collects up to 15 whole air canisters per flight
- Canisters analyzed in lab
- Measures ambient T, RH, P, wind speed and wind direction, as well system P and flow at 1 Hz
- Computer programed or piloted flights

Canisters – air is captured in flight in 8-15 discreet samples
WASPP collects whole air samples and meteorological data
WASPP collects whole air samples and meteorological data
Lab based calibrations show excellent agreement between sensors and standards.
Analysis of whole air samples

Module has been built to couple to a VOC analyzer
- NCAR Trace Organic Gas Analyzer (TOGA)

VOCs – there are many and the combined reactivity is what’s important

- Duplicate subsamples
- Representative measurement (no detectable influence from rotor wash)

The x-axis shows names of a subset of measured VOCs
The y-axis shows concentrations on a particular day
Field Studies: WASPP VOC measurements in Broomfield, Boulder
Field Study: WASPP VOC reveal vertical gradients Nov. 29 4:08 pm
Oil and Gas VOC regional influence

- VOC sources have unique “fingerprints” to identify them

O&NG iC5/C5 ratio = 0.8 – 1.0 vs.
Urban Emissions iC5/C5 ratio = 1.5-2.5

WASPP measurements

FRAPPÉ – Aircraft program

Hornbrook et al. 2015
Summary

• We need more ABL chemical composition measurements to resolve vertical gradients of many chemical species

• UAS are one attractive means of making these measurements

• WASPP observes strong vertical gradients in VOCs, even in well mixed ABL

• WASPP can accurately attribute key source signatures of pollution, e.g. those from oil and natural gas

Thank you!
WASPP Status

Contact for more details and availability: Eric Apel, apel@ucar.edu, 303-497-1452

Publication on system:
Potential WASPP Uses

1. Provide detailed VOC spatial gradients for ground-based studies

2. VOC Source Attribution


4. Test assumptions surrounding VOC gradients given temporal evolution of the ABL