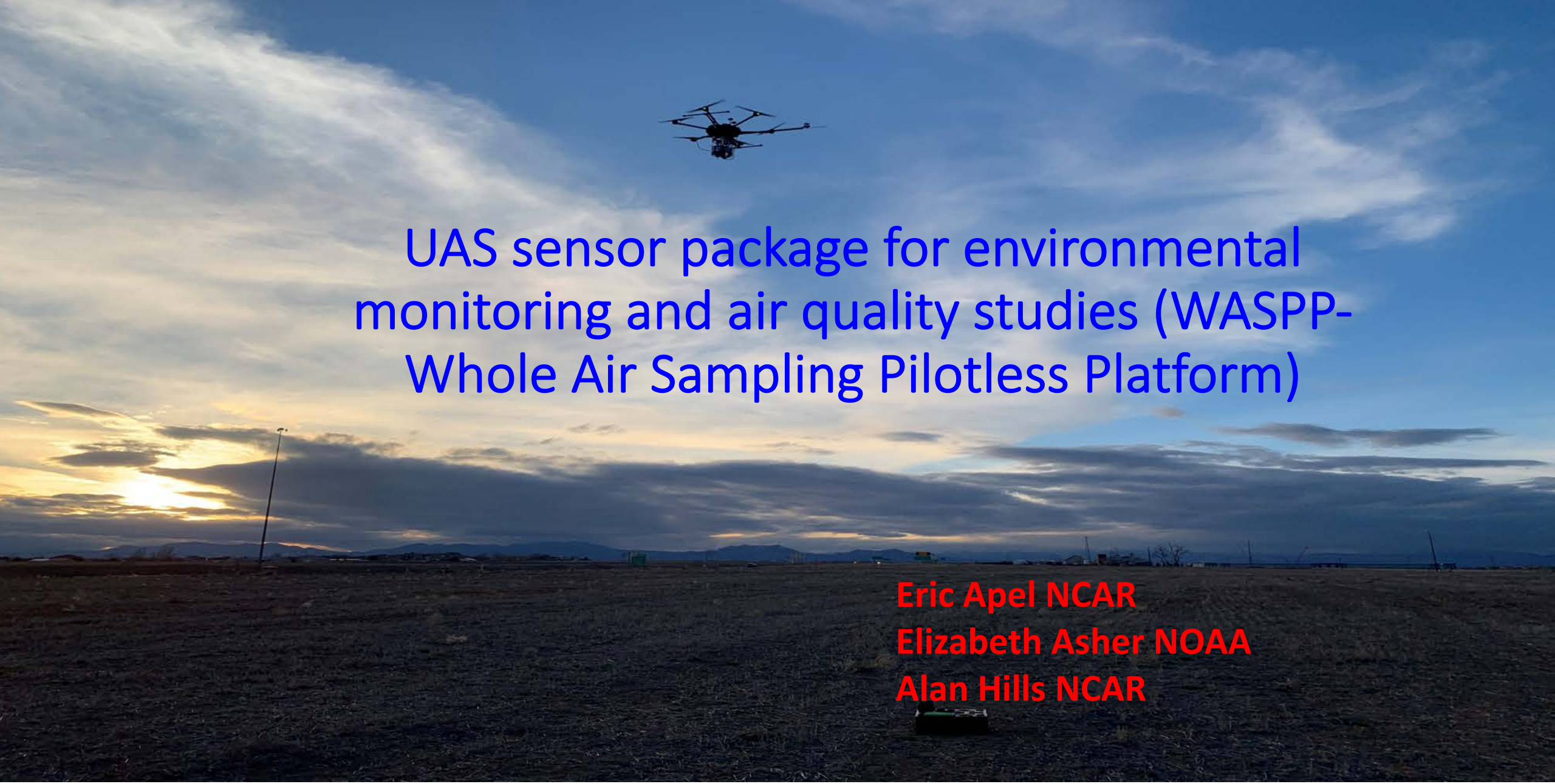


UAS sensor package for environmental monitoring and air quality studies (WASPP-Whole Air Sampling Pilotless Platform)

Eric Apel NCAR
Elizabeth Asher NOAA
Alan Hills NCAR

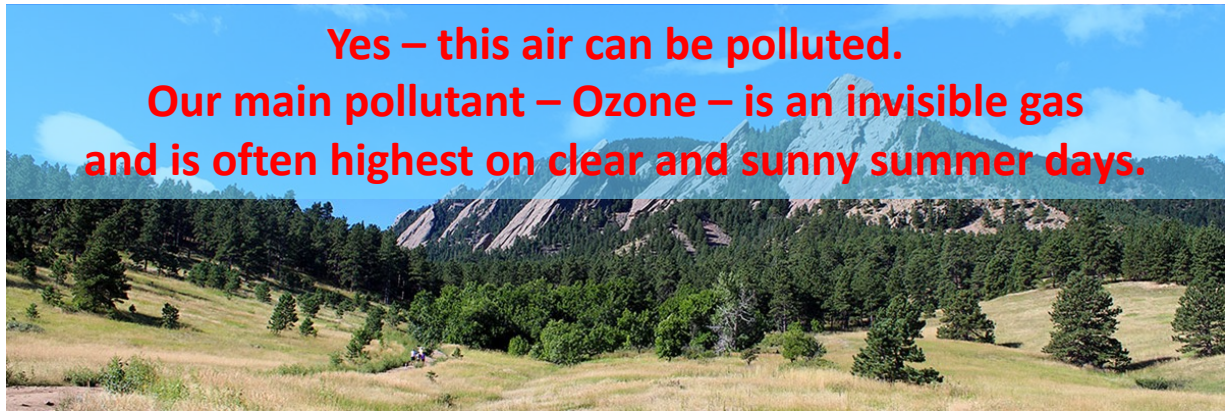
ACOM NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Air quality on the Front Range is a problem

Fires impact air quality

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

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



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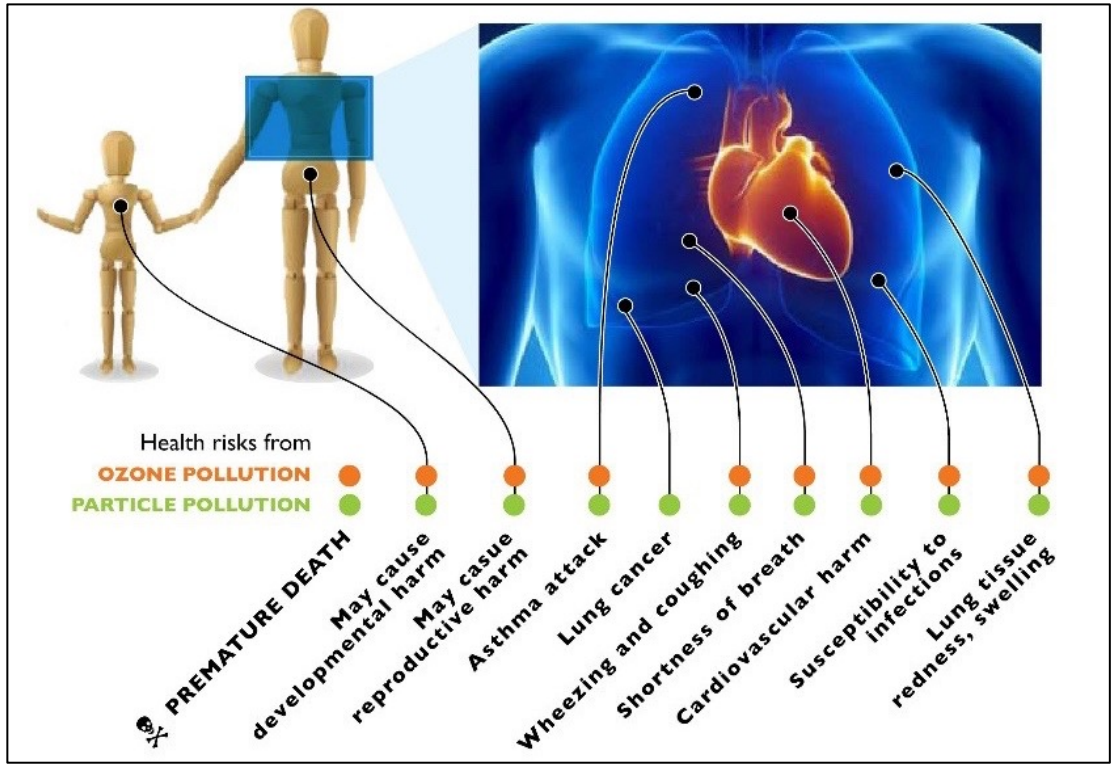
Air quality studies and air quality forecasts? Why do we care?

Health Impacts of Ozone and PM2.5



Picture: American Lung Association

Health Costs ~Billions $

World Health Organization

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
IBRD • IDA

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.

ELSEVIER

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

Air pollution emissions and damages from energy production in the U.S.: 2002–2011

Paulina Jaramillo [a], Nicholas Z. Muller [b]

~131 billion dollars

Show more

https://doi.org/10.1016/j.enpol.2015.12.035

Get rights and content

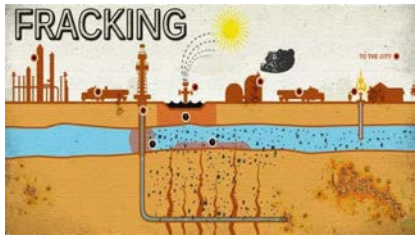
Air pollution/Ozone chemistry – some basics

Ozone

NOx

(a “secondary” pollutant)

VOCs



Sources

(primary pollutants)

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

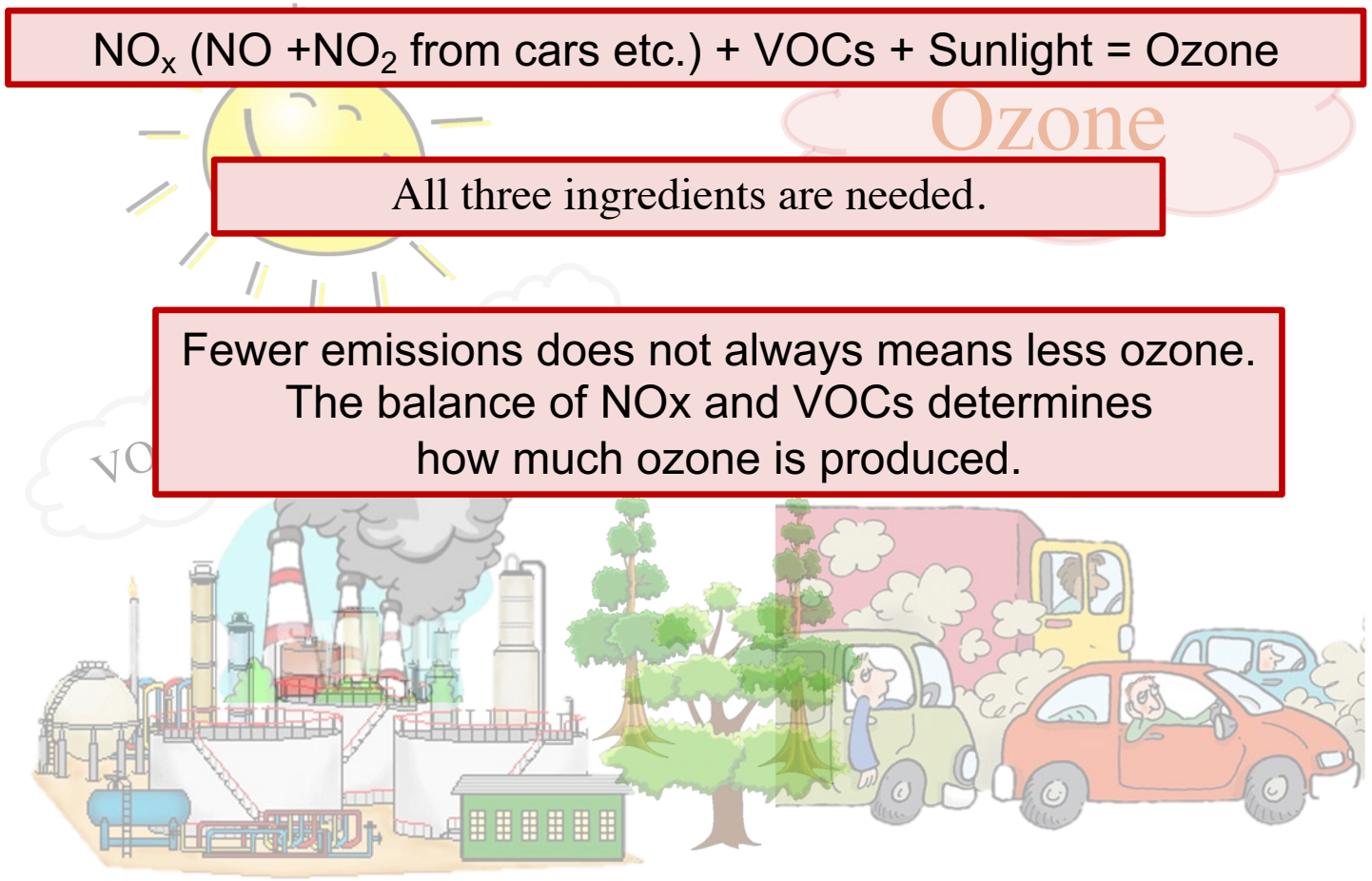
NO_x = NO + NO_2 from cars, industry, fires

Air pollution/Ozone chemistry – review

NO_x (NO +NO_2 from cars etc.) + VOCs + Sunlight = Ozone

All three ingredients are needed.

Fewer emissions does not always means 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

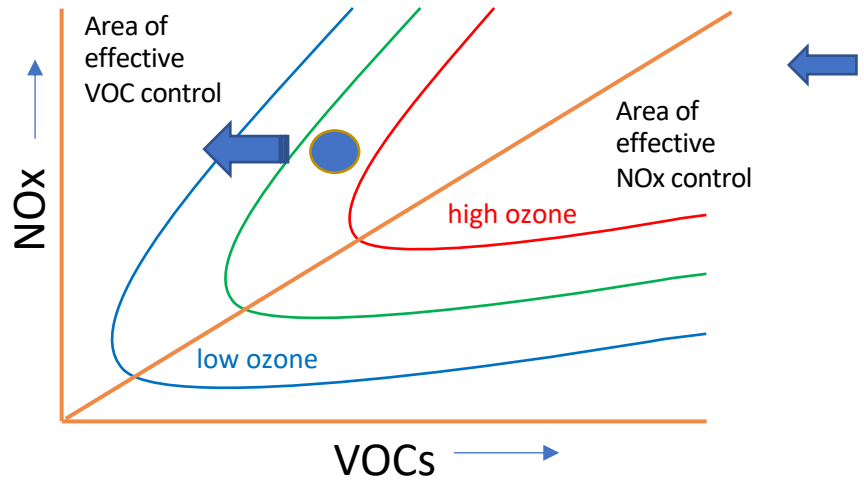
  Mitigation Strategies for Primary Pollutants are clear: Reduced Emissions = Reduced concentrations

  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*

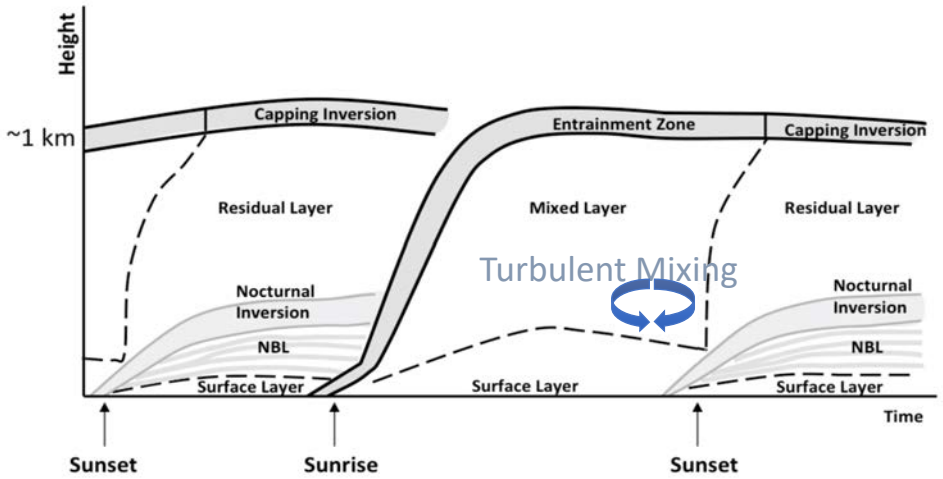
* non-local transport of pollution could counteract local mitigation strategies!

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



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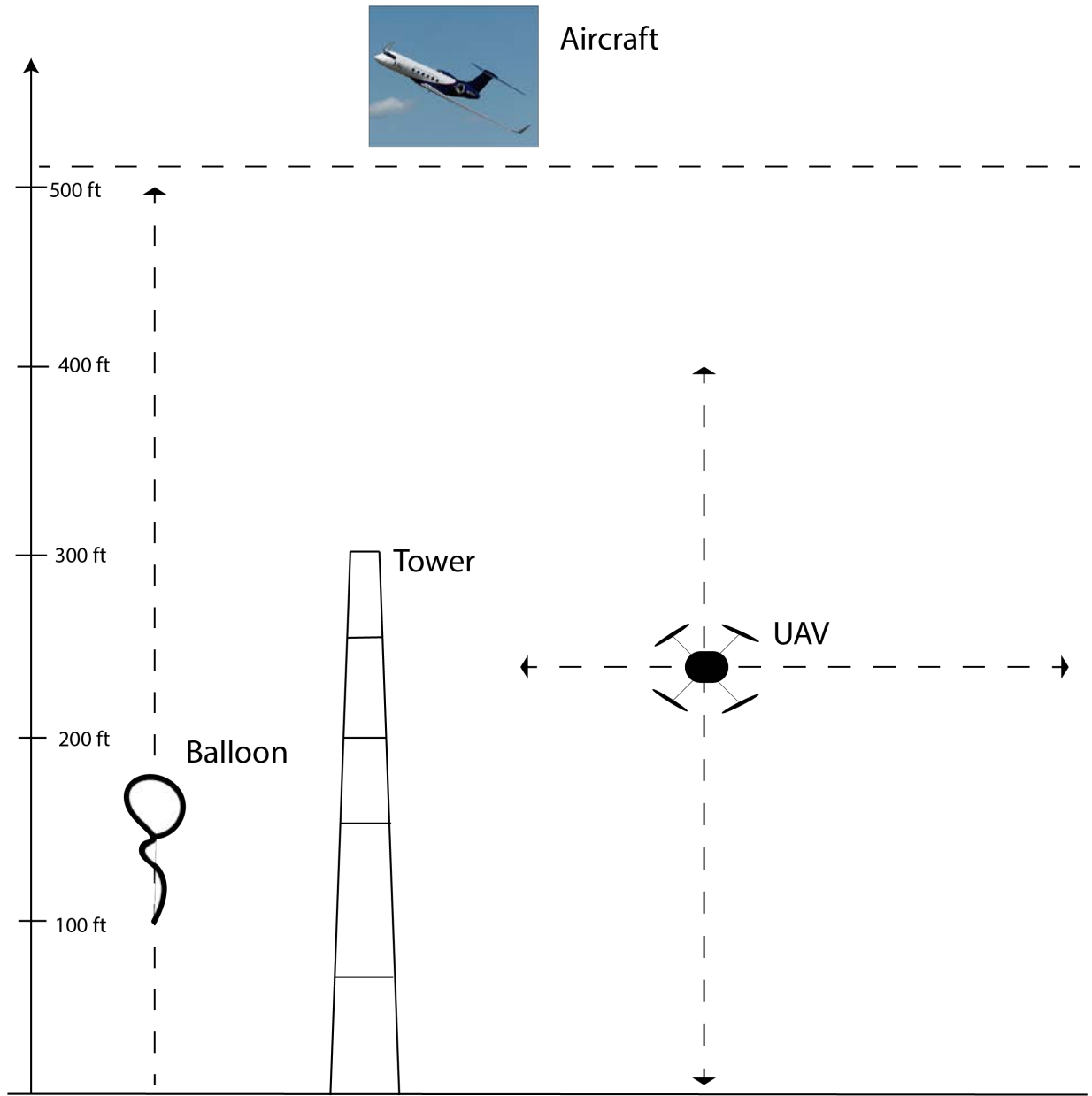
Niche for monitoring air quality by UAS?

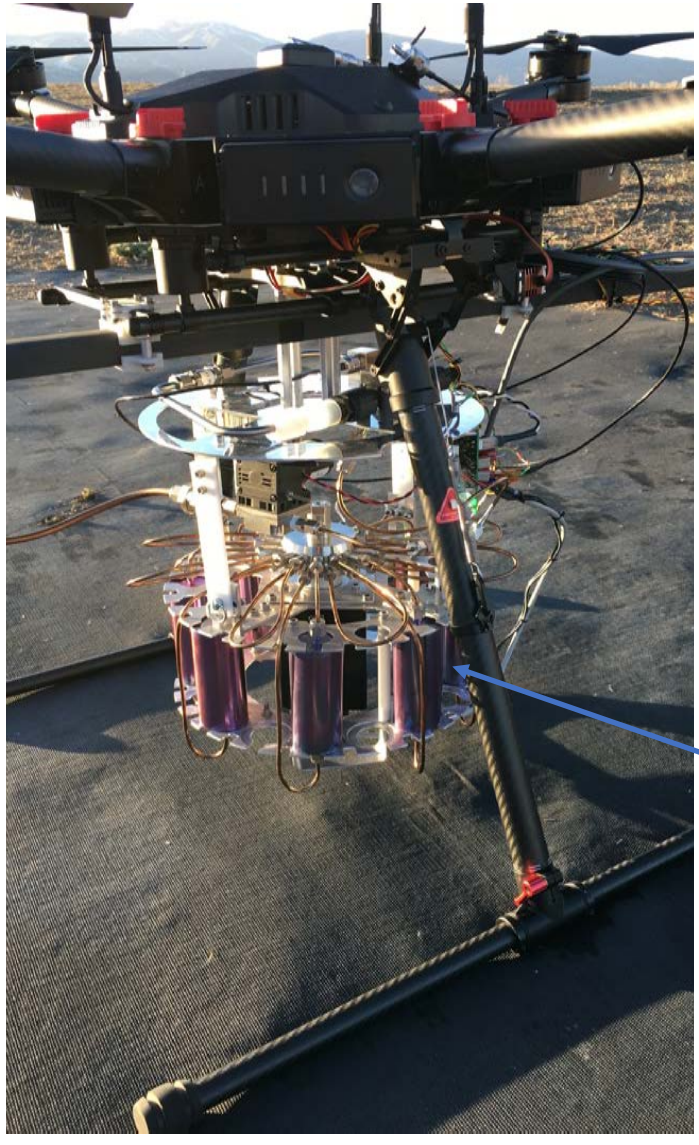
UAS measurements for air quality studies:

- Multi-rotor UAVs can repeatedly and map out spatial gradients in the vertical and horizontal
- Pollution source attribution
- Air quality forecasts



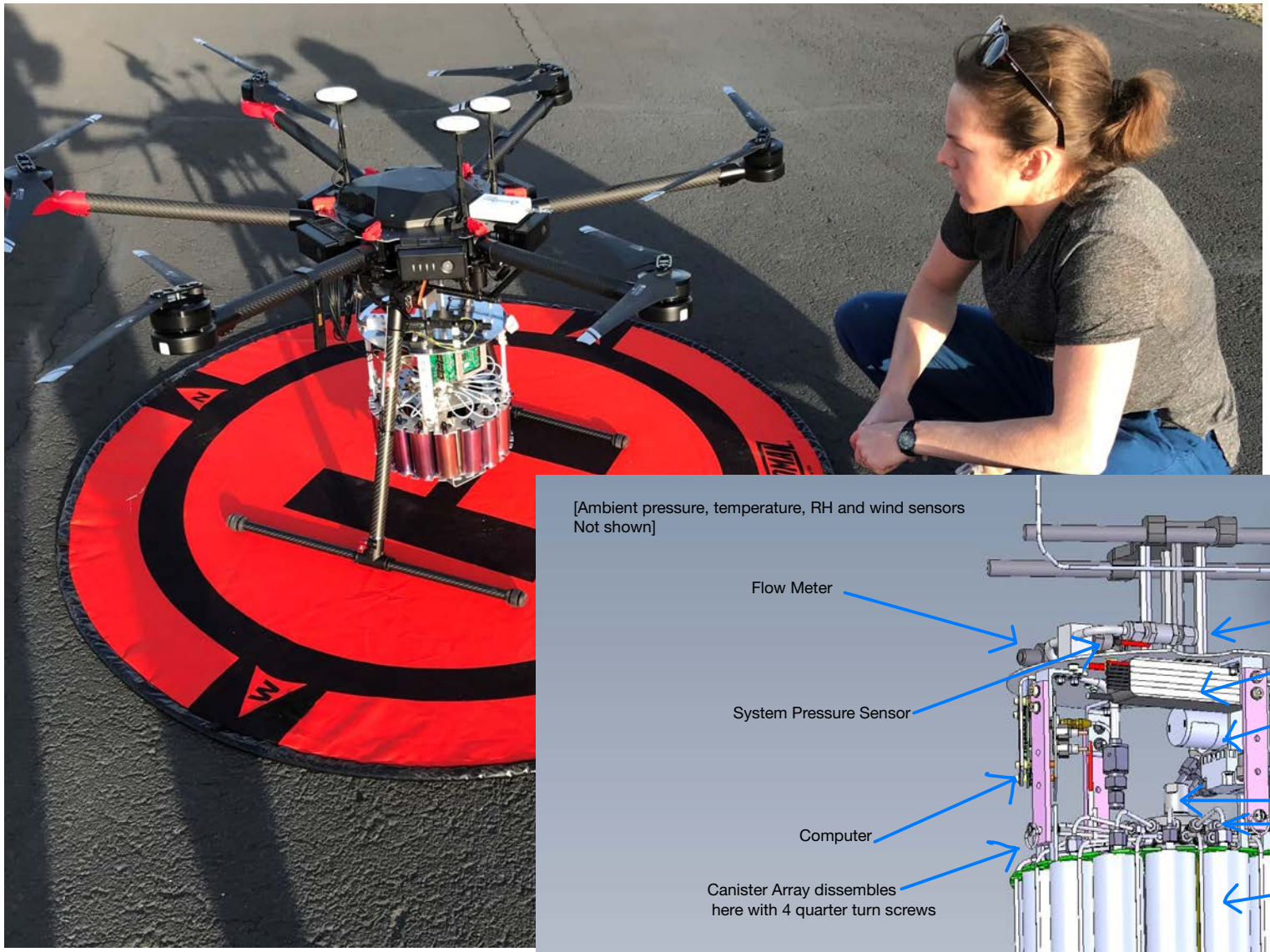
WASPP collects whole air samples and meteorological data

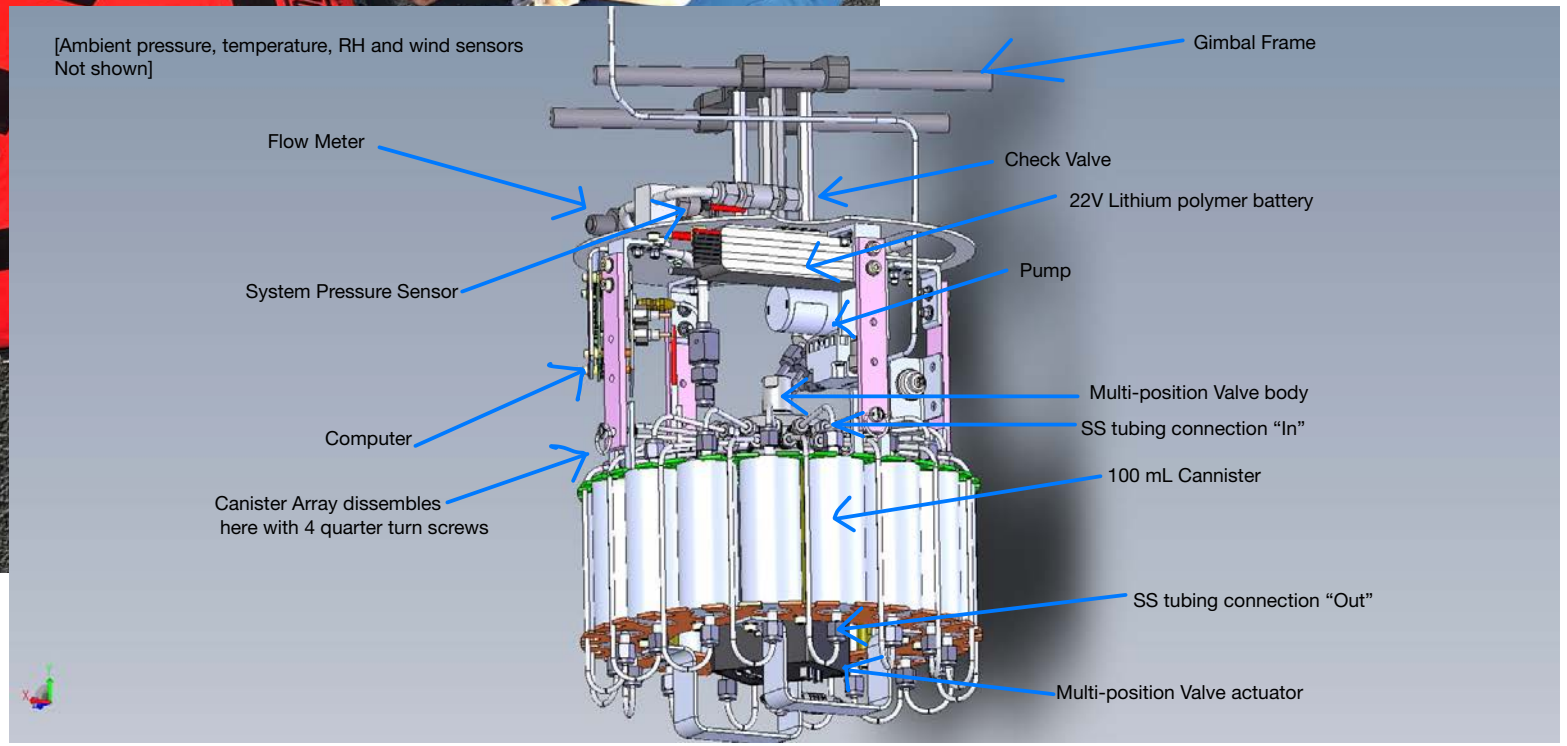
- Collects up to 15 whole air canisters per flight
- Canisters analyzed in lab
- Measures ambient T, RH, P, wind speed and wind direction, as well system P and flow at 1 Hz
- Computer programed or piloted flights



Canisters – air is captured in flight in 8-15 discreet samples

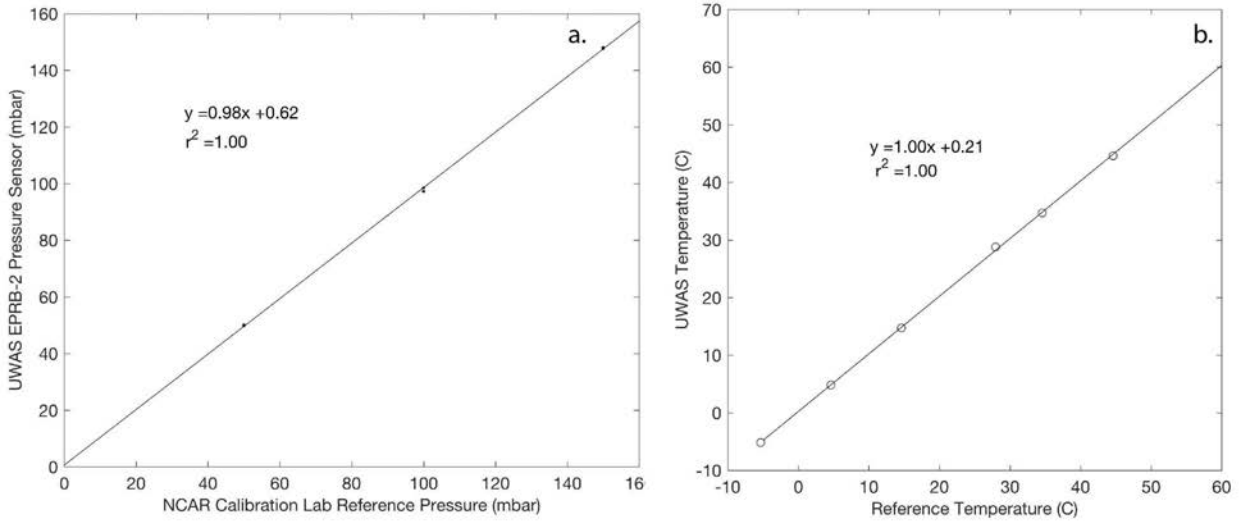
WASPP collects whole air samples and meteorological data

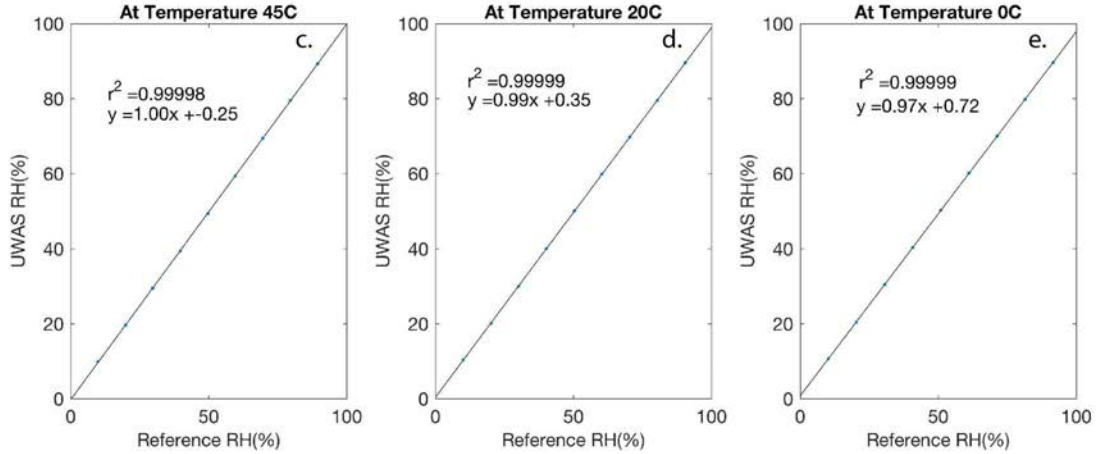




WASPP collects whole air samples and meteorological data

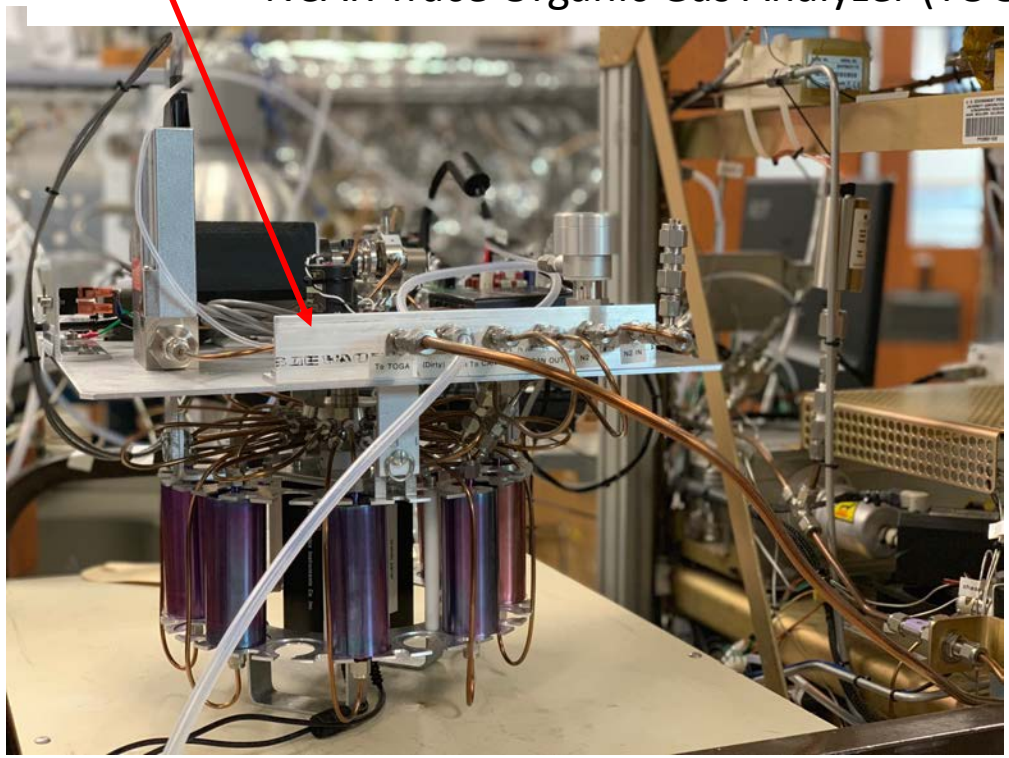
Lab based calibrations show excellent agreement between sensors and standards





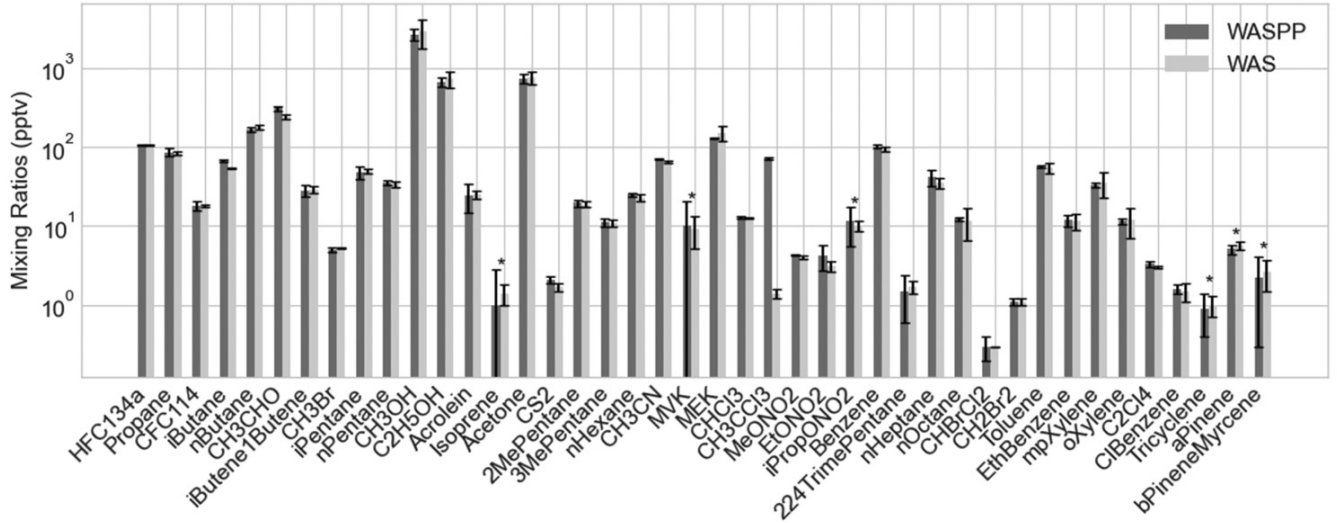
Analysis of whole air samples

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



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

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

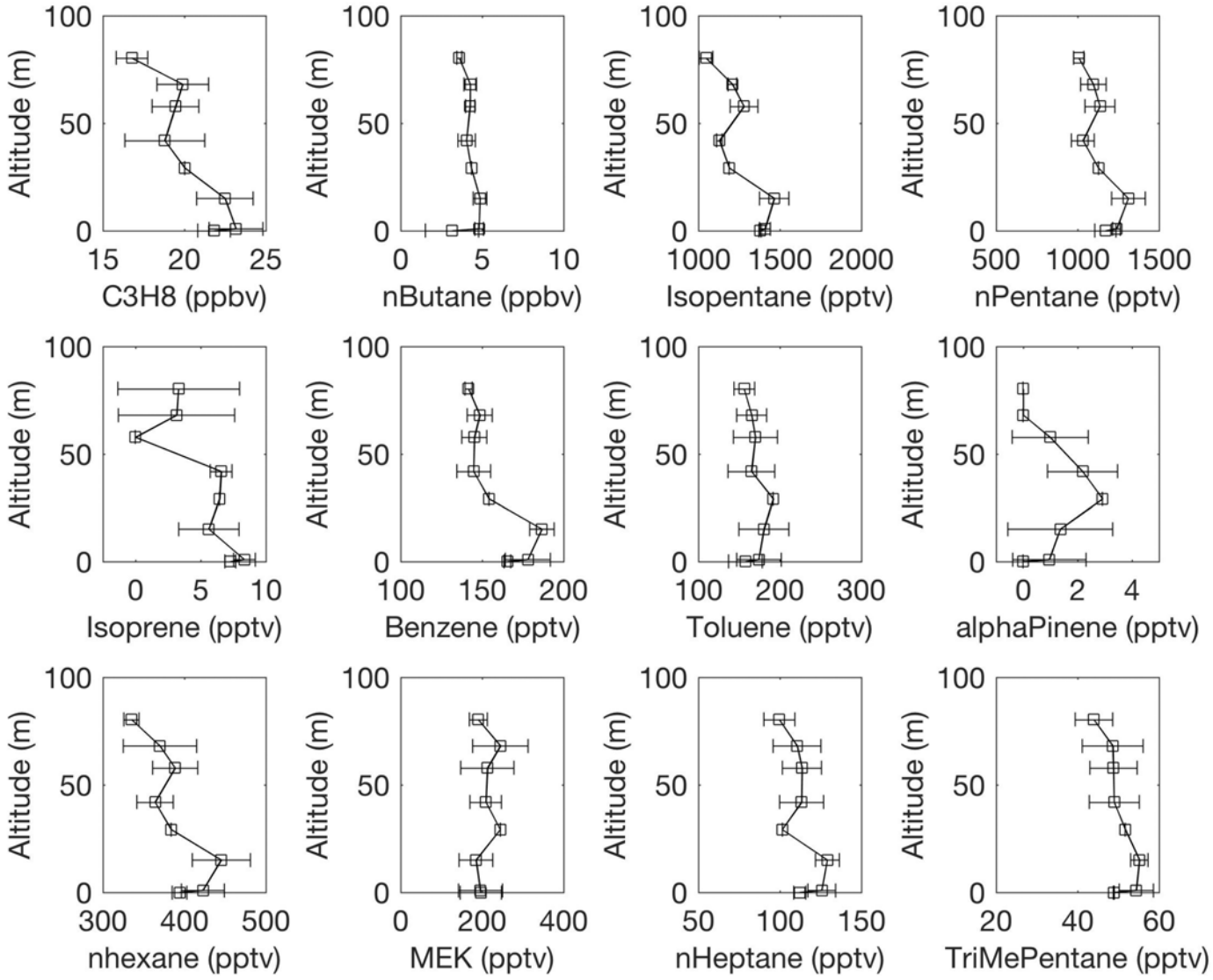


The x-axis shows names of a subset of measured VOCs

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

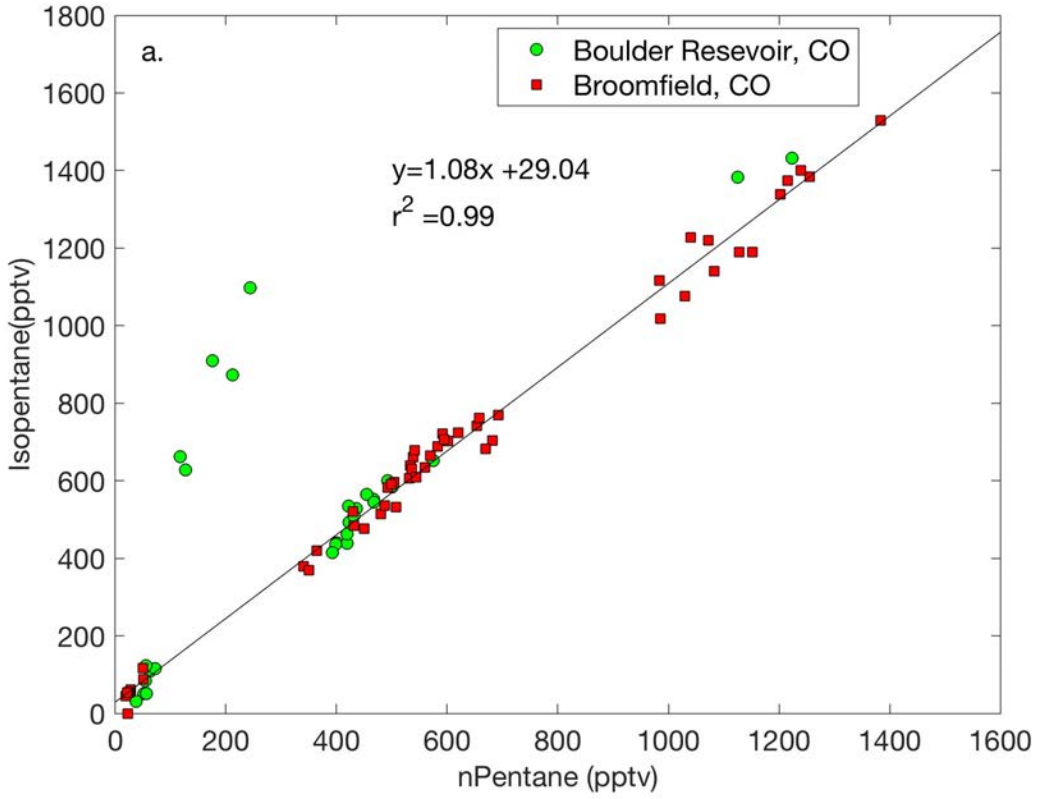


Oil and Gas VOC regional influence

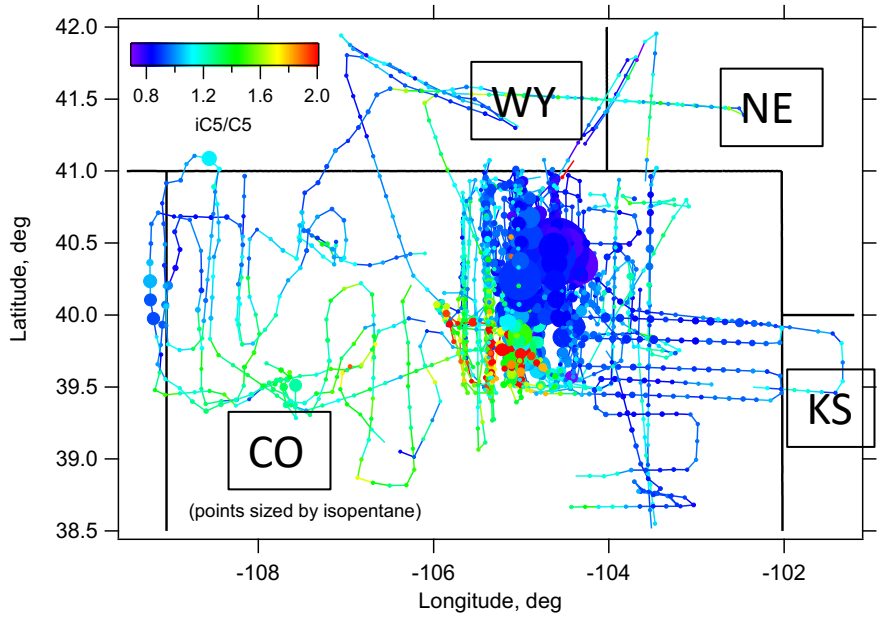
-VOC sources have unique “fingerprints” to identify them

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:

Asher, E., Apel E.C. et al., Unpiloted Aircraft System Instrument for the Rapid Collection of Whole Air Samples and Measurements for Environmental Monitoring and Air Quality Studies, Environmental Science & Technology 55 (9), 5657-5667, DOI: 10.1021/acs.est.0c07213, 2021.

Potential WASPP Uses

1. Provide detailed VOC spatial gradients for ground-based studies
2. VOC Source Attribution
3. Mass Balance Flux Estimates near VOC sources
4. Test assumptions surrounding VOC gradients given temporal evolution of the ABL