

FRAPPÉ, DISCOVER-AQ and Implications for Air Quality in Colorado

EPA National Air Monitoring Conference
8/9/2016



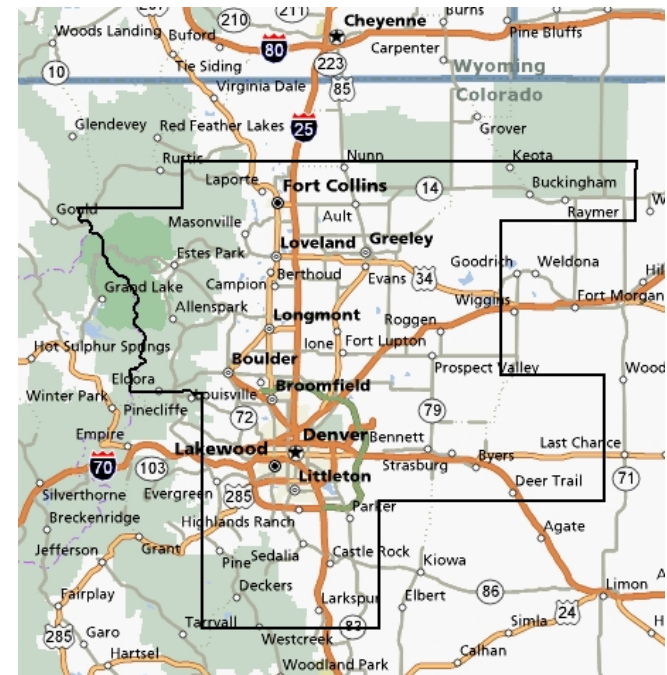
COLORADO

Air Pollution Control Division

Department of Public Health & Environment

Air Quality Problem

- ▶ North Front Range of Colorado is non-attainment for ozone
- ▶ Rocky Mountain National Park suffers from acid deposition
- ▶ Variety of sources for air pollution in the area
 - Urban
 - Vehicle
 - Oil and gas development
 - Agriculture
 - Power plants
 - Refinery
 - Long range transport

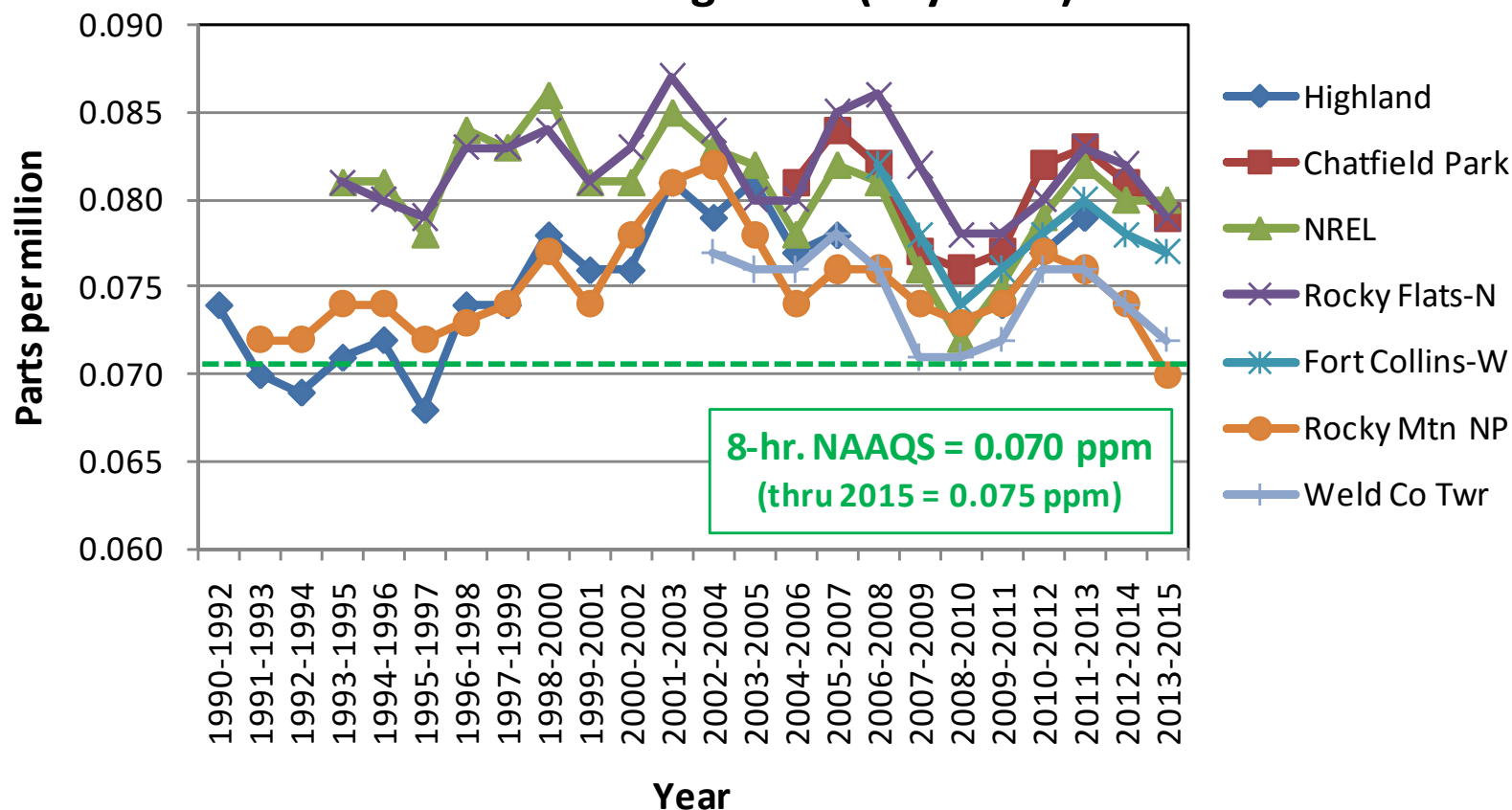


Colorado North Front Range

Ozone Trends

8-Hour Ozone --- 3-year Avg. of 4th Max.

North Front Range area (key sites)



Air Quality Improvements ?

- ▶ Ozone is a hard issue to resolve
 - NO_x (or VOC) reductions can reduce or increase O₃ depending on the “chemical regime”
 - “Background” ozone is elevated
- ▶ We have done all the “easy” things
 - Catalytic converters, emission equipment on vehicles
 - Emissions reductions for oil and gas
 - Emission reductions for EGUs
- ▶ Need for “smarter”, better informed solutions
- ▶ Need for more comprehensive measurements
 - Air quality models mostly informed and “validated” by sparse ground-based observations of very few “criteria pollutants”
 - Pollutants move around horizontally and vertically
 - Spatially separated emissions come into play during different meteorological situations; recirculation effects
 - Climate change impacts

Front Range Air Quality Studies

- Two simultaneous major research field campaigns occurred in Colorado from July 17–August 18, 2014
 - FRAPPÉ (NCAR)
 - DISCOVER–AQ (NASA)
- Overlap with Other Studies
 - Oil and Gas Emissions and Dispersion Study
 - Agriculture Early Warning Pilot
 - Ongoing Efforts from CSU, CU, NOAA

Major funding agencies:

Partners:

EPA, NOAA, NPS, others



Colorado Department
of Public Health
and Environment

NASA DISCOVER–AQ Study

- ▶ “Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality”
- ▶ 4th and final DISCOVER–AQ mission
- ▶ Study design is to:
 - Relate column observations from satellites to surface concentrations for aerosols and key trace gases
 - Characterize differences throughout the day between surface and satellite observations of air pollutants
 - Examine horizontal scales of variability affecting satellites and air quality modeling
- ▶ <http://discover-aq.larc.nasa.gov/>

NCAR FRAPPÉ Study

- ▶ “Front Range Air Pollution and Photochemistry Experiment”
- ▶ The study was designed to characterize and understand summertime air quality in the Northern Front Range
- ▶ The study assessed how emissions from various sources interact with the meteorological conditions of the Front Range to impact overall air quality, in particular for ozone:
 - Local and regional sources (urban, industry, industrial, oil and gas extraction and related activities, agriculture and livestock/feeding operations, biogenic emissions, wildfires)
 - Import of emissions from UT, WY, CA, and from outside the U.S. (Asia)
 - Natural emissions (biogenic volatile organic compounds, nitrogen oxides, lightning, stratospheric ozone)
- ▶ <http://www2.acd.ucar.edu/frappe>

FRAPPÉ



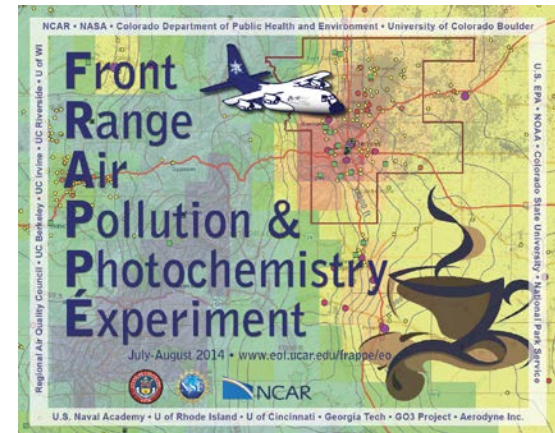
- ▶ Organized by NCAR
- ▶ C-130 aircraft, 15 flights
- ▶ Continuous measurements
 - ground
 - aircraft
 - mobile labs
- ▶ Comprehensive AQ & Met sampling, modeling, forecasts
- ▶ 15 organizations/universities

6 Major Ground Sites (joint with DISCOVER-AQ)

Ft. Collins West
BAO Tower (Erie)
Platteville
La Casa NCore
NREL
Chatfield Park

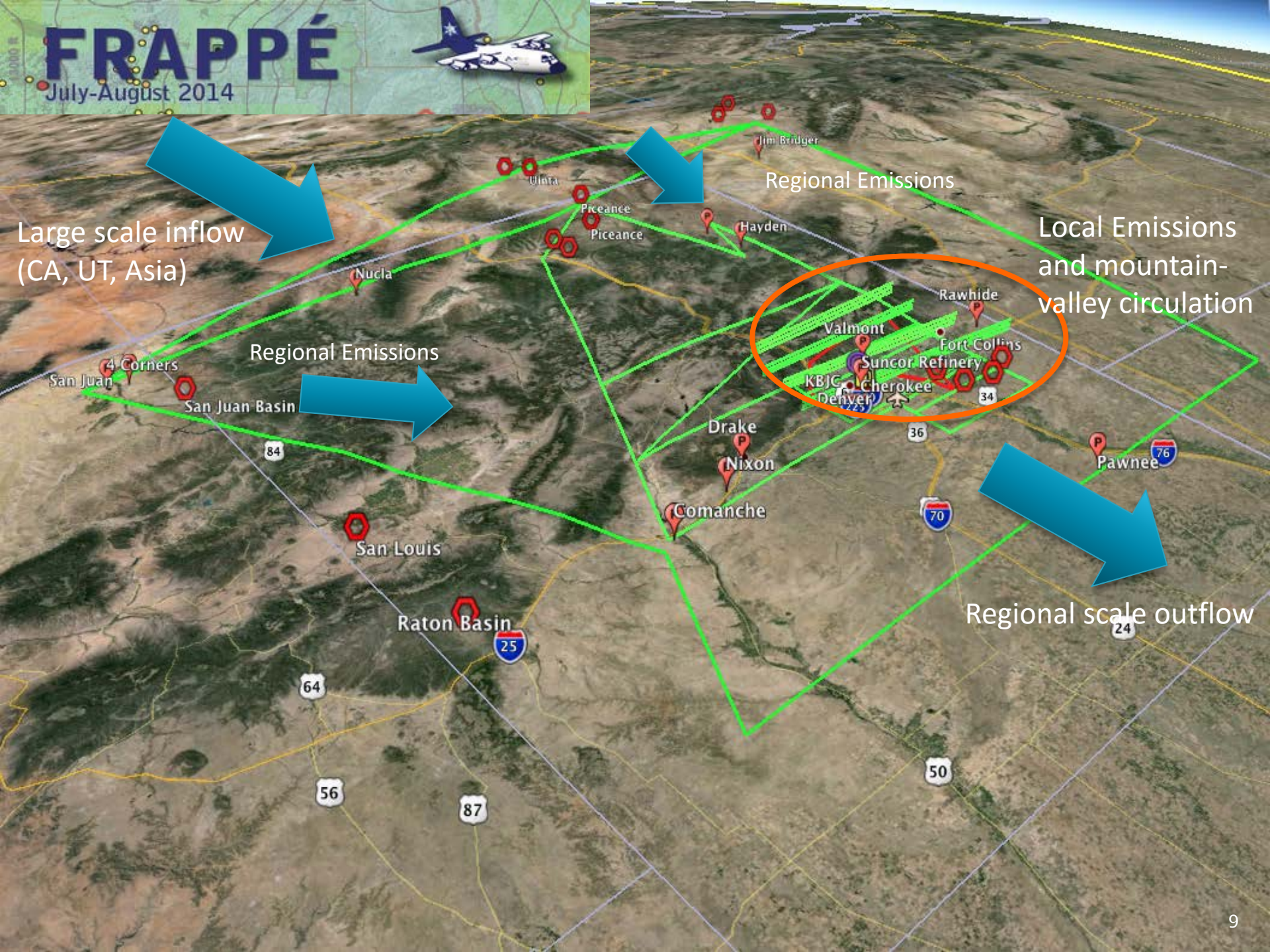


- + additional ground sites
- + tethered balloons



FRAPPÉ

July-August 2014

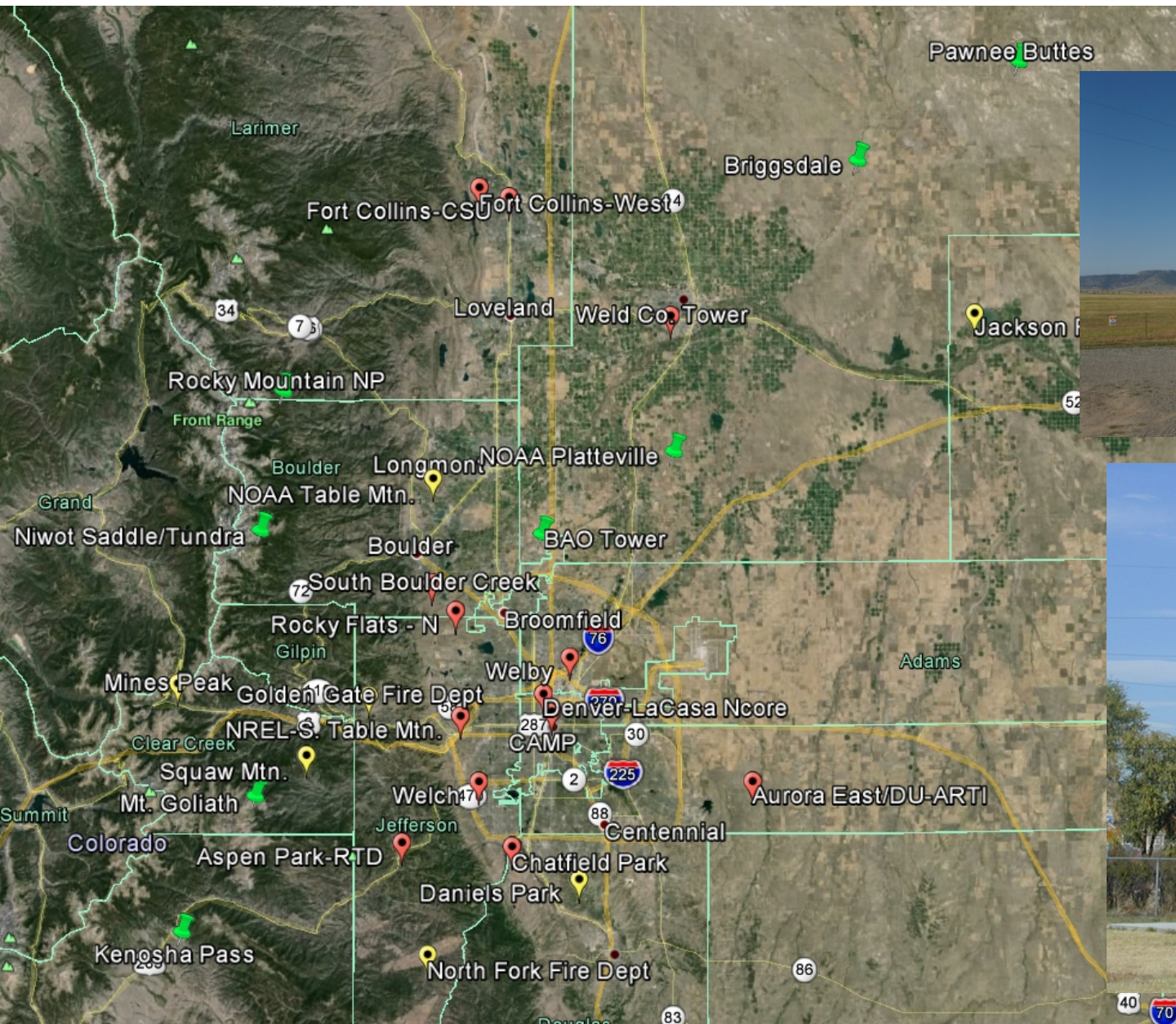


FRAPPÉ NCAR C-130 aircraft

- C-130 outfitted with comprehensive chemistry payload
 - ▶ Flexible itinerary and flight path (based on forecasts) used to:
 - characterize circulation and transport patterns
 - examine pollutant transport into and out of Colorado
 - quantify point and area sources within and outside Front Range
- ▶ Measurements included:
 - Methane, ethane, formaldehyde
 - VOCs (canisters)
 - Ammonia
 - Aerosol measurements
 - NO_x/NO_y measurements
 - SO_2



Fixed Ground Ozone Sites

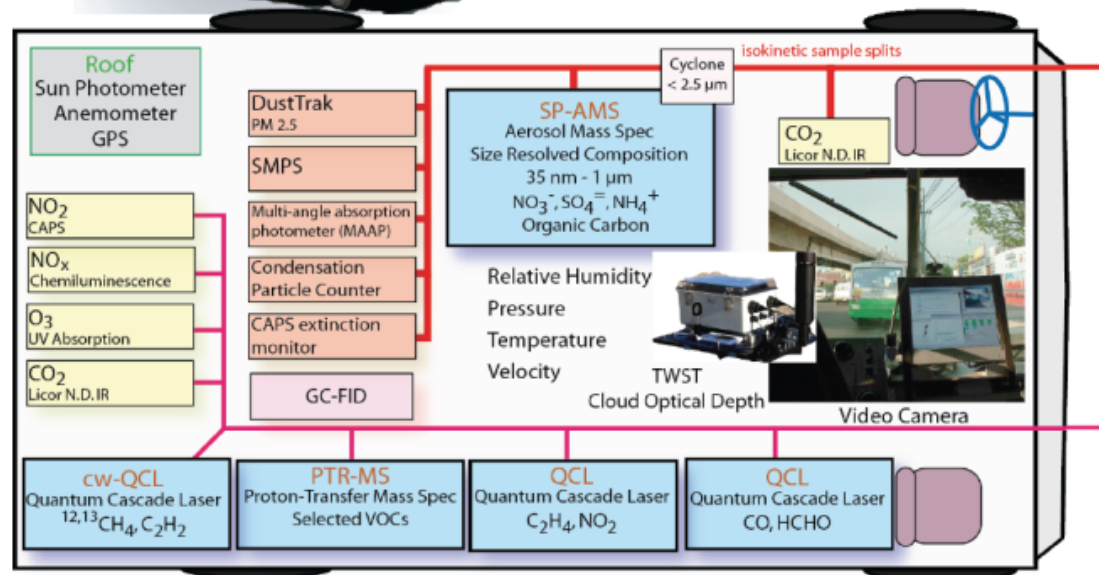


Mobile Labs

- ▶ Mobile vans instrumented similarly to aircraft
- ▶ Can get near sources to characterize
- ▶ Operate while driving
- ▶ Mobile labs were operated by Aerodyne, NOAA, NPS and researchers from several universities

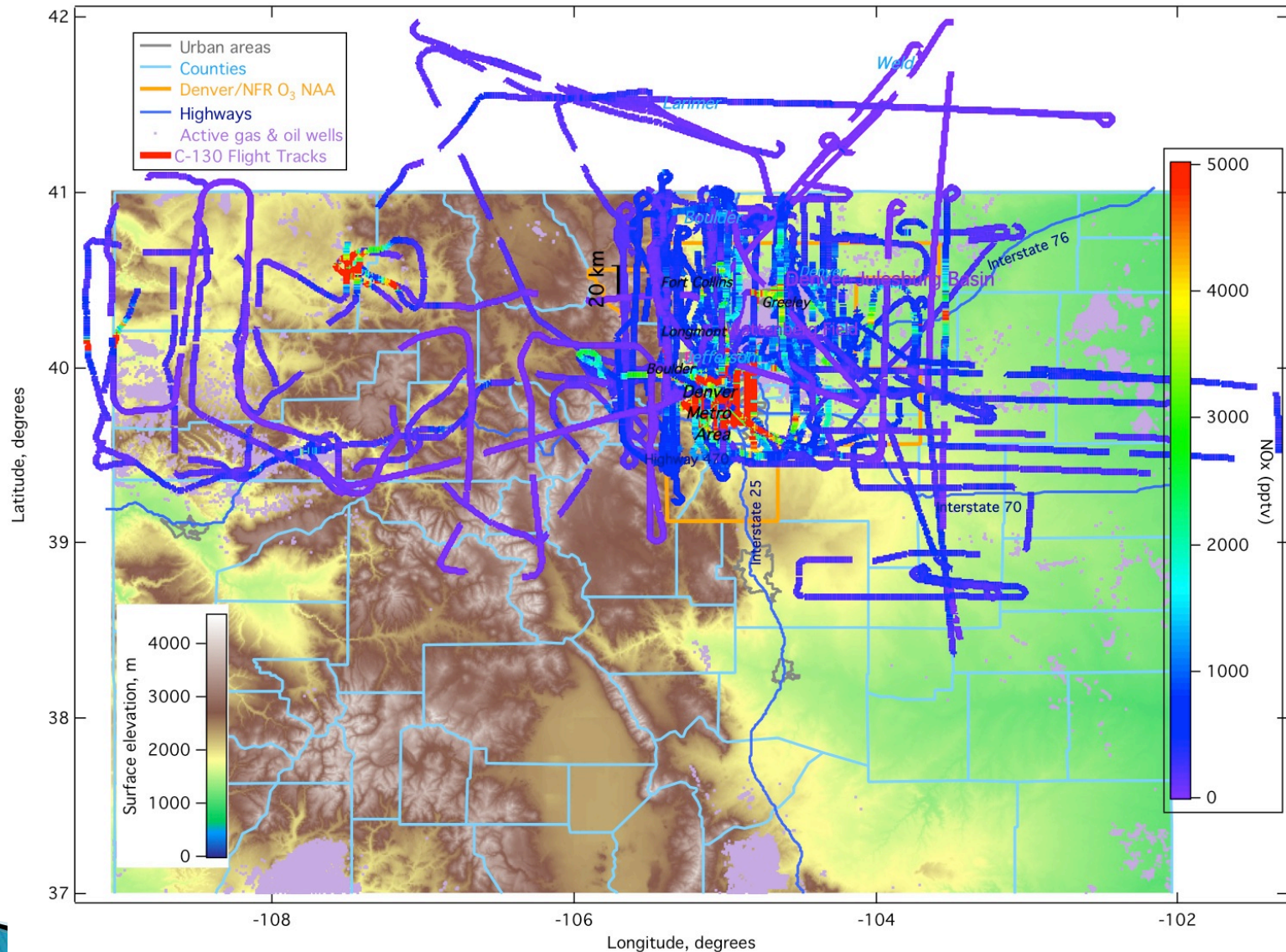


Aerodyne Mobile Lab
DISCOVER-AQ, 2013



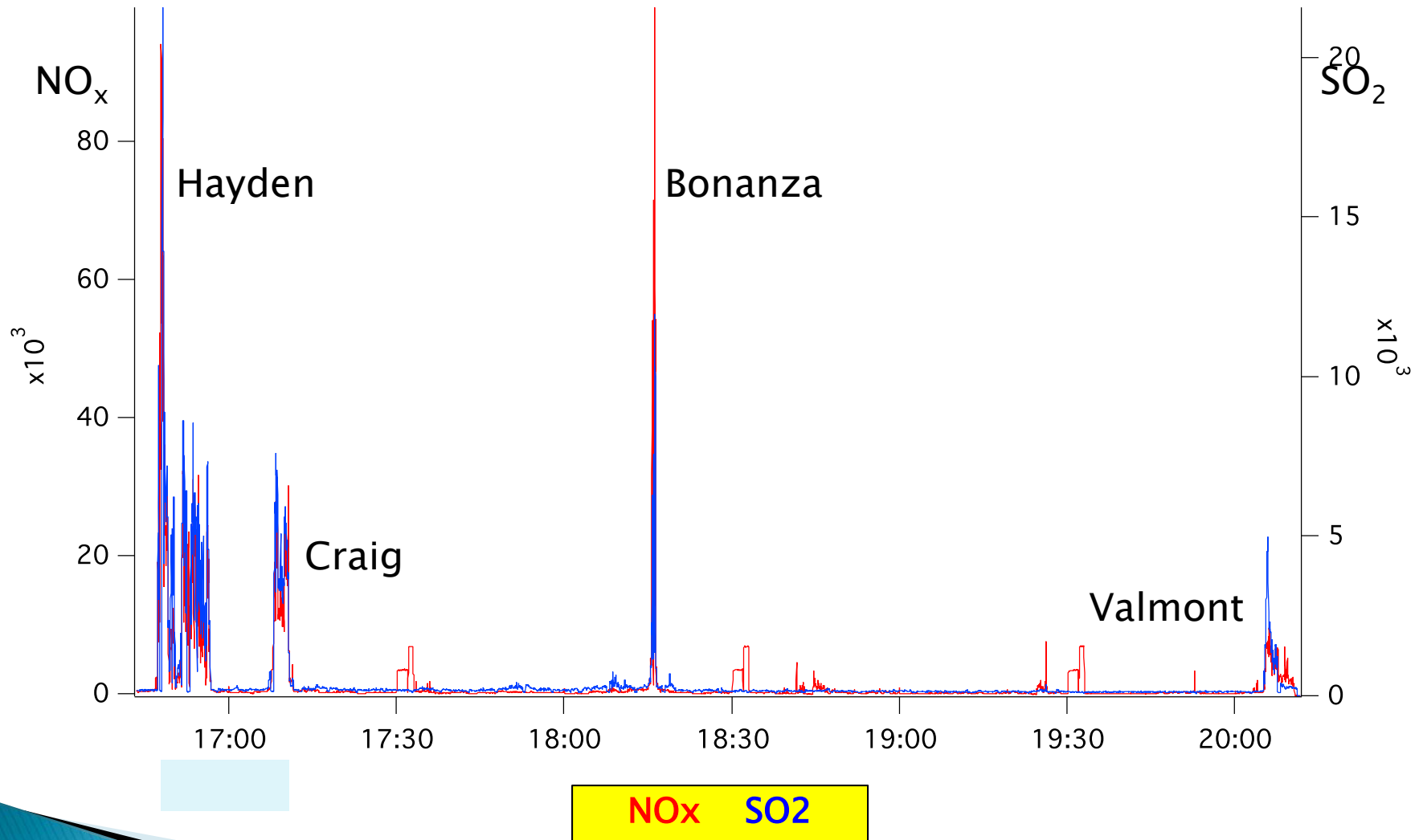
Source: Aerodyne, Inc.

C-130 NO_x = urban/source influence

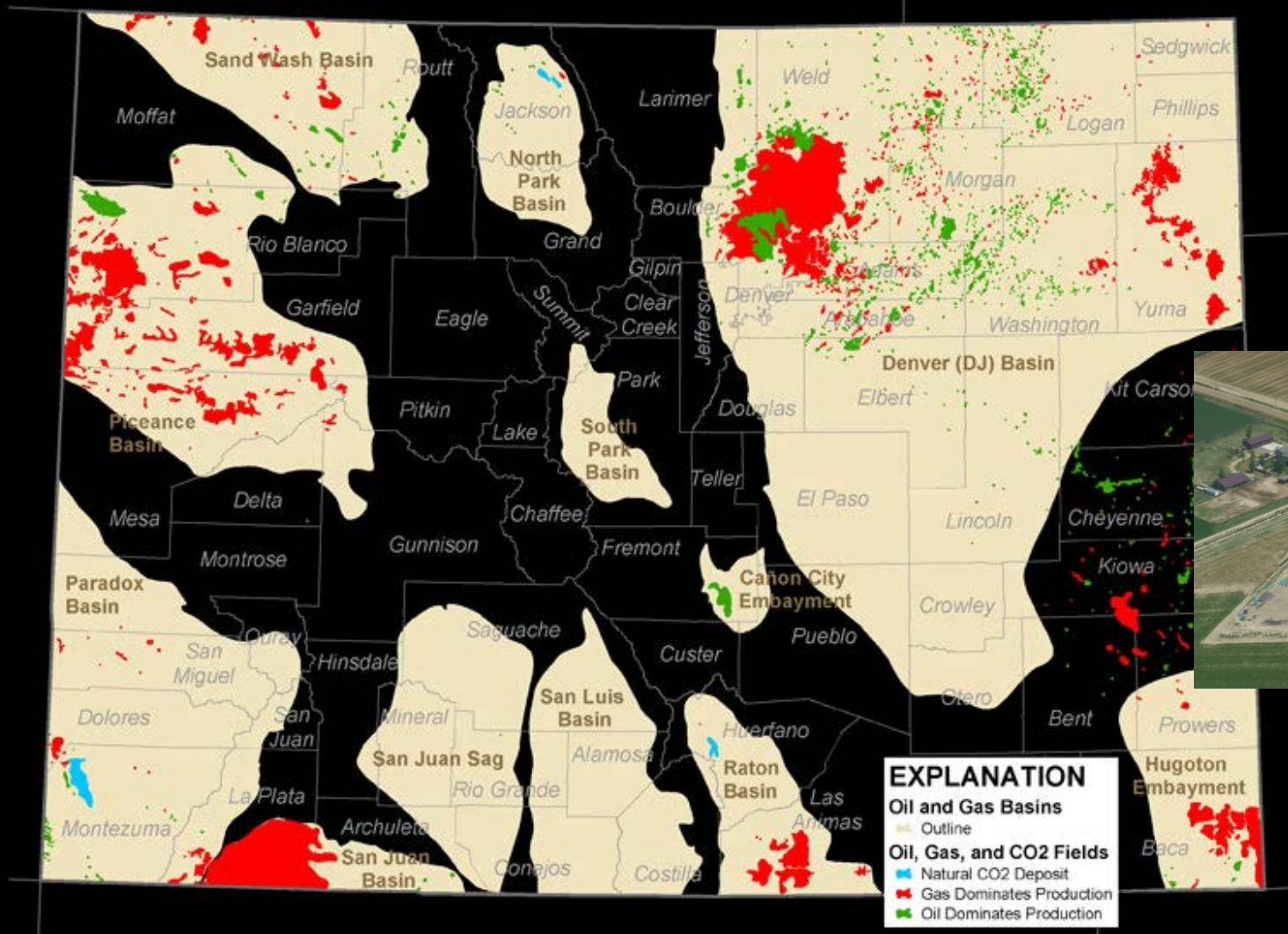


Higher over urban areas and power plants

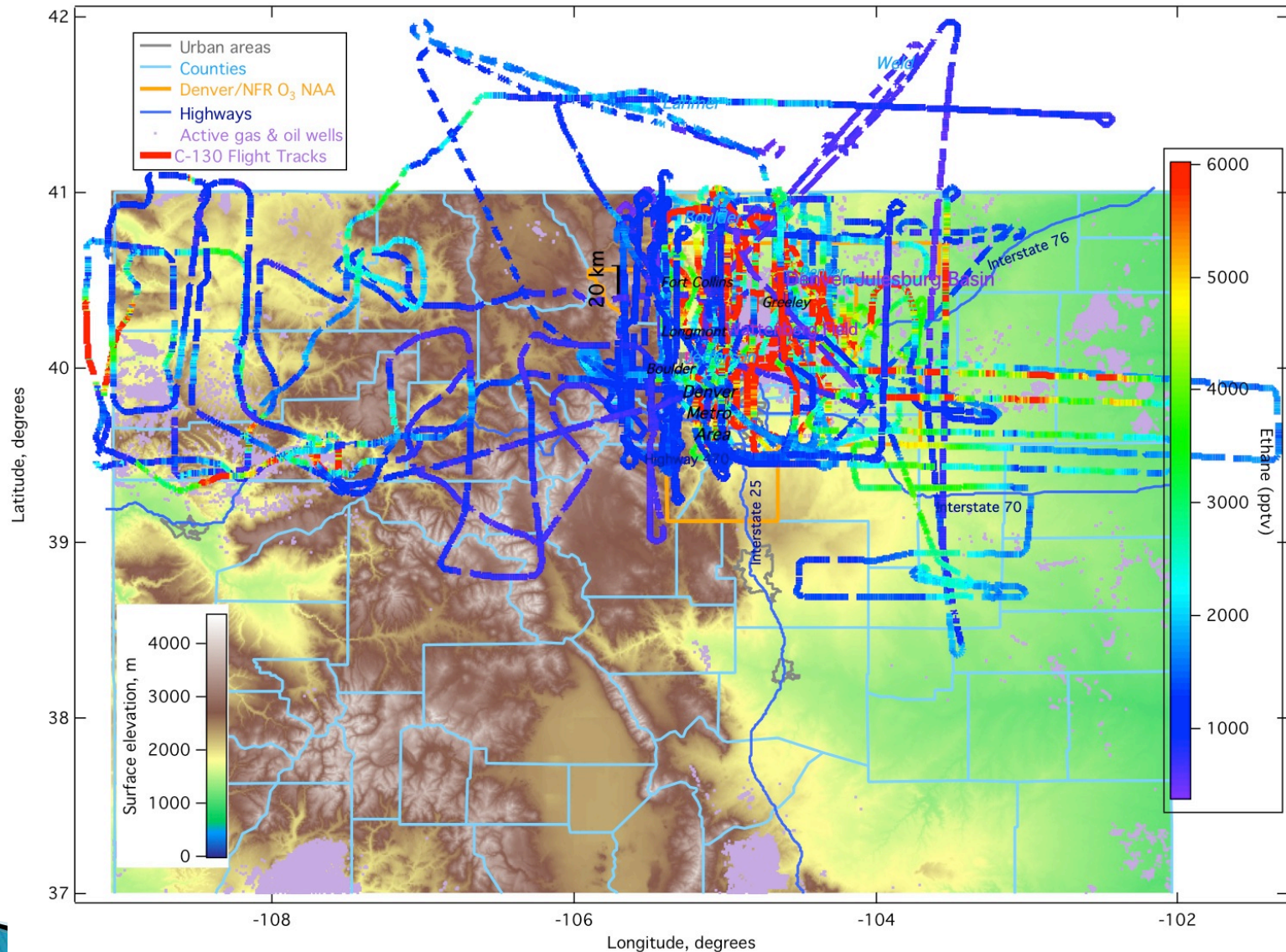
Power Plants – C-130 NO_x and SO₂



Oil and Gas Development

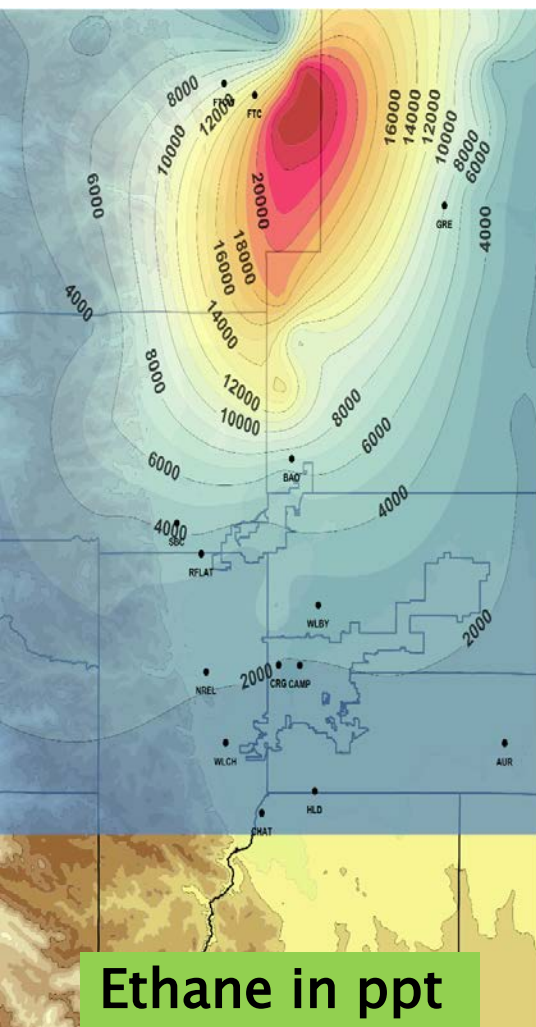


C-130 Ethane = Oil and gas influence

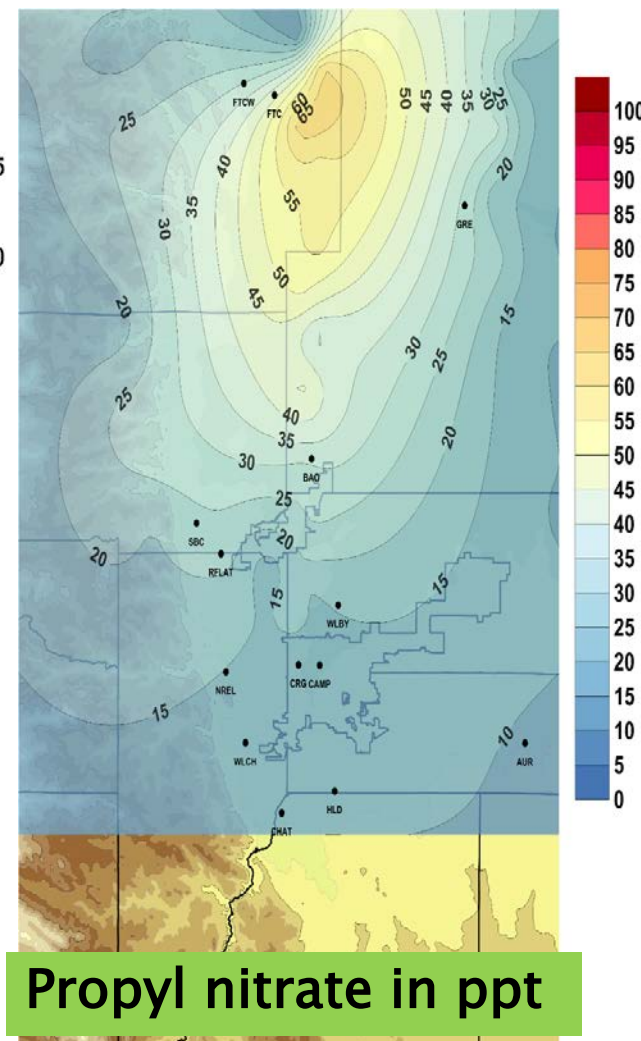
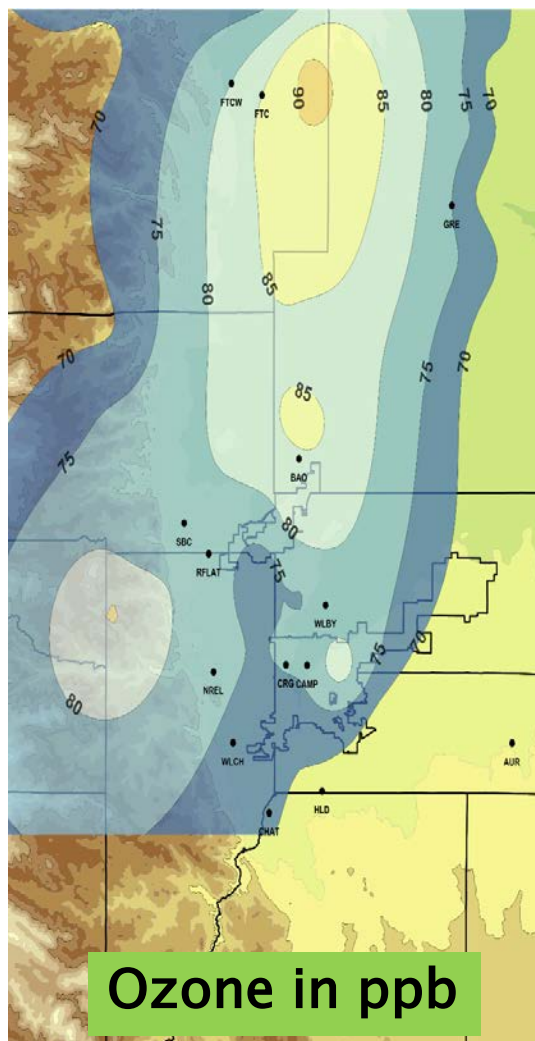


Higher over oil and gas development areas

C-130 Ethane/Ozone/Propyl Nitrate

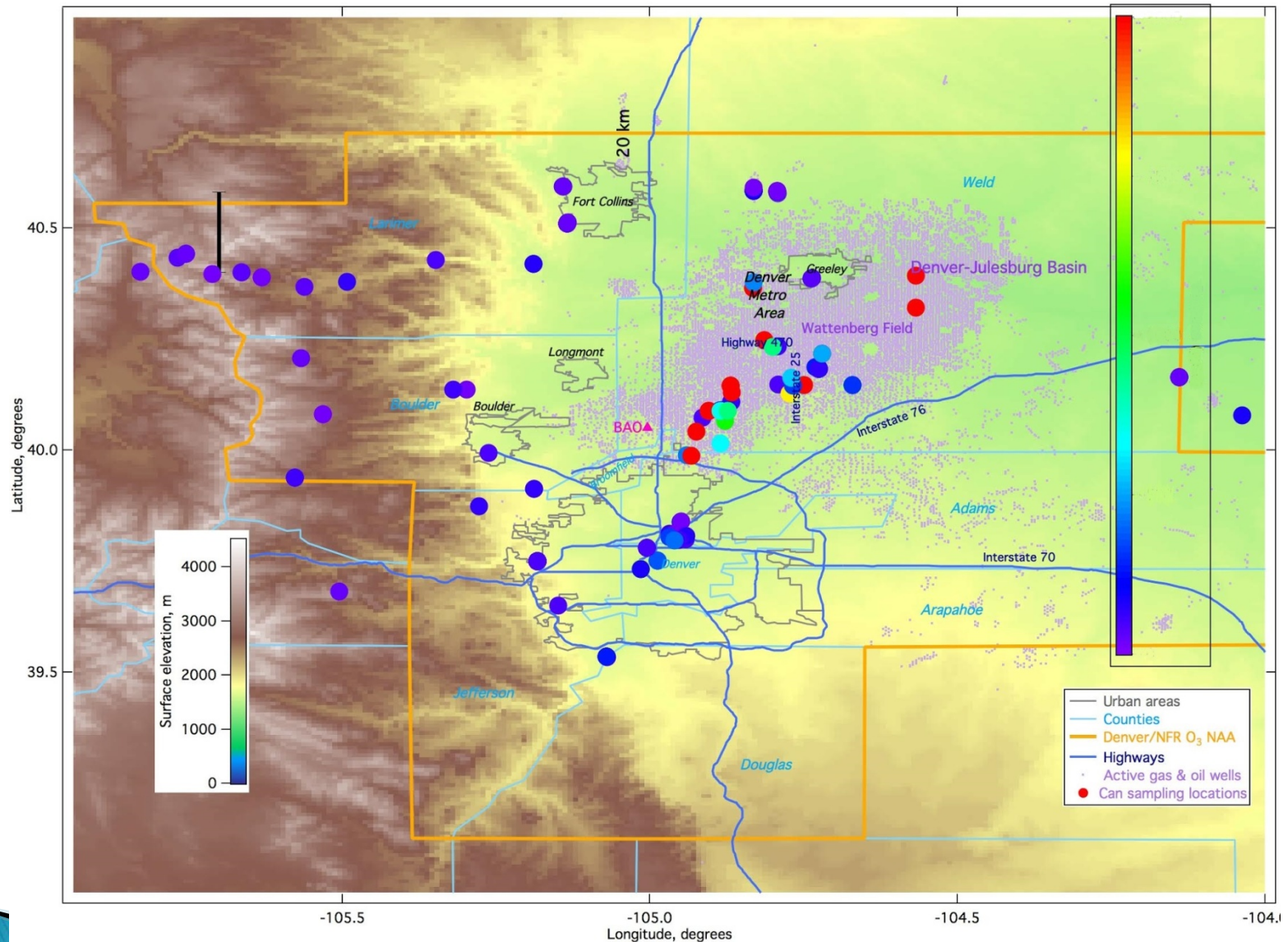


Oil and gas development



Data from the NCAR C130 aircraft flight on August 3, 2014, showing high ethane, high ozone, and high propyl nitrate east of Ft. Collins

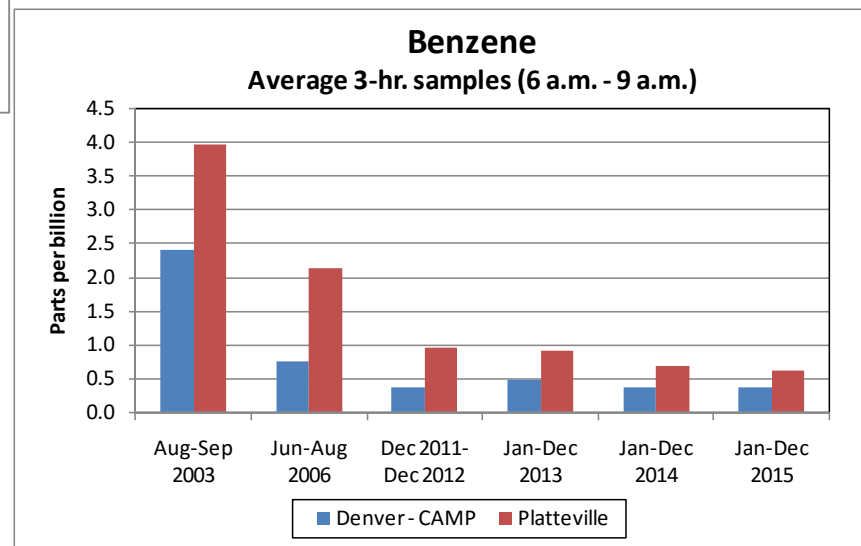
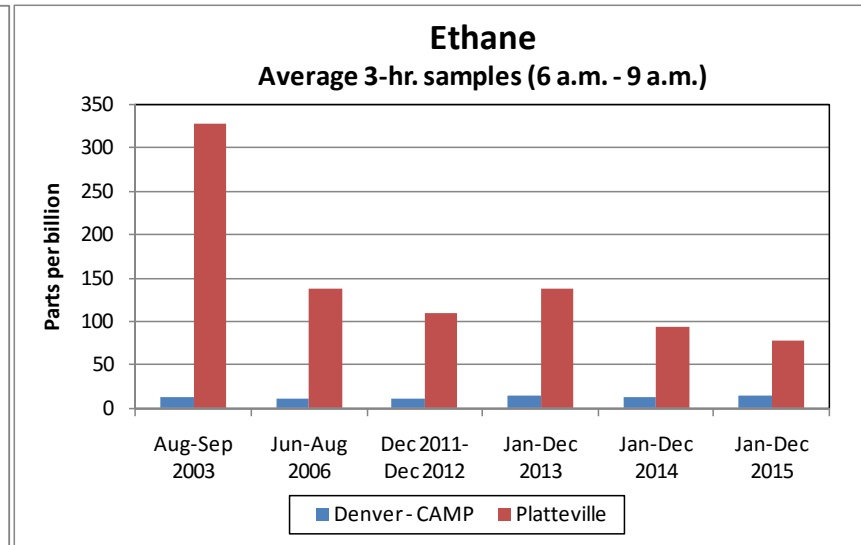
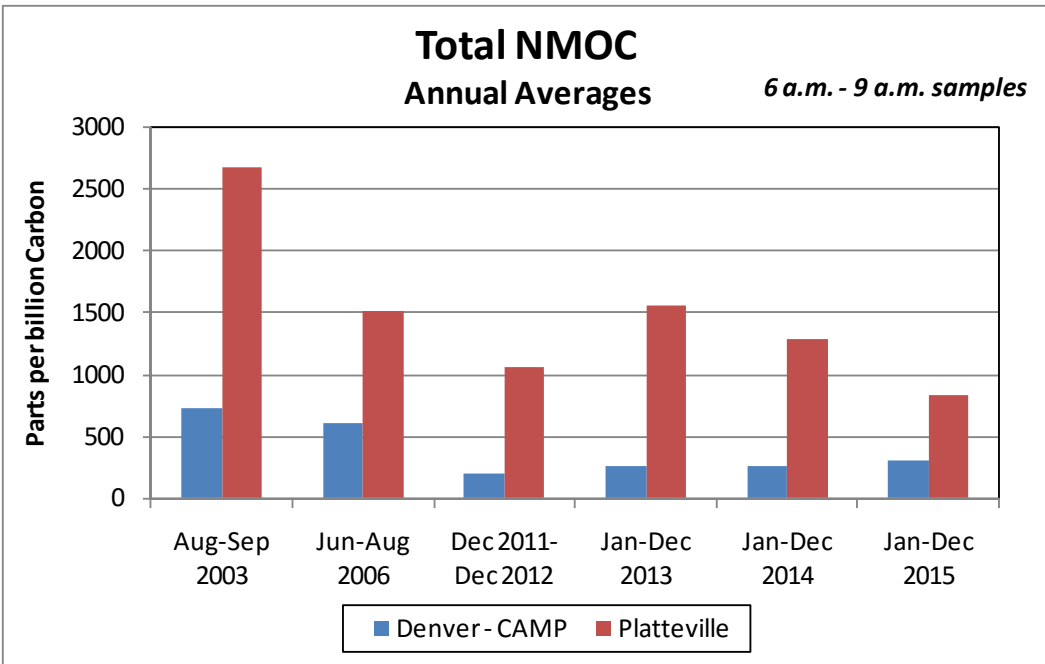
Benzene from Canisters



Benzene higher in oil & gas development area

CDPHE (ground)

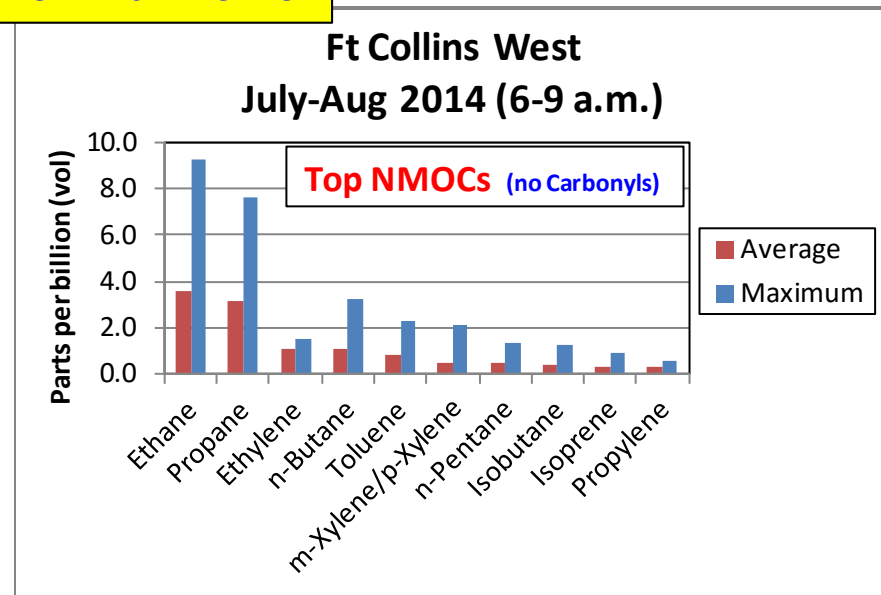
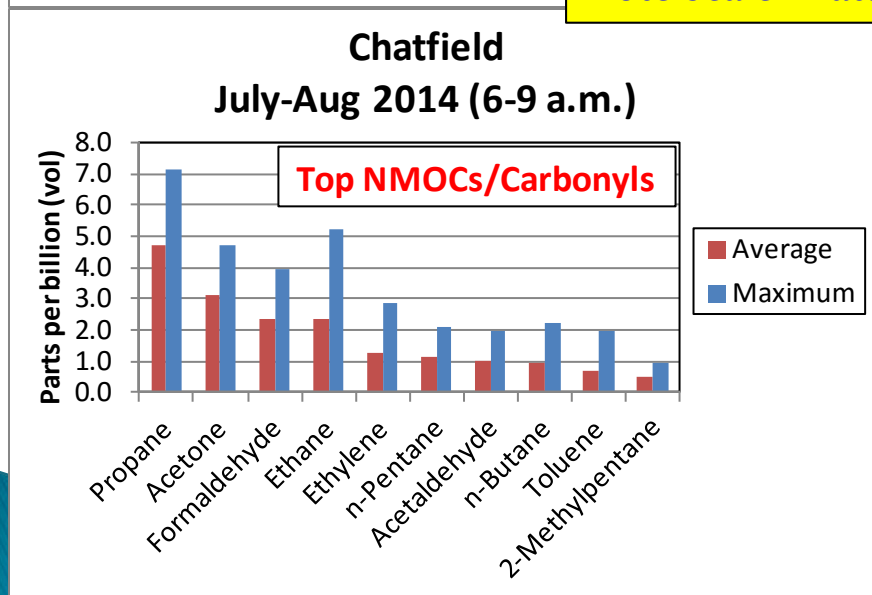
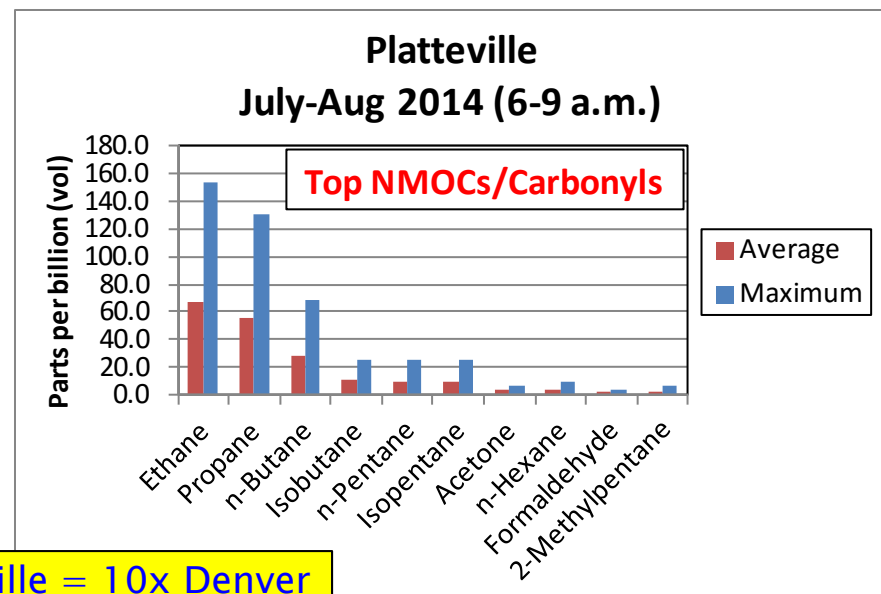
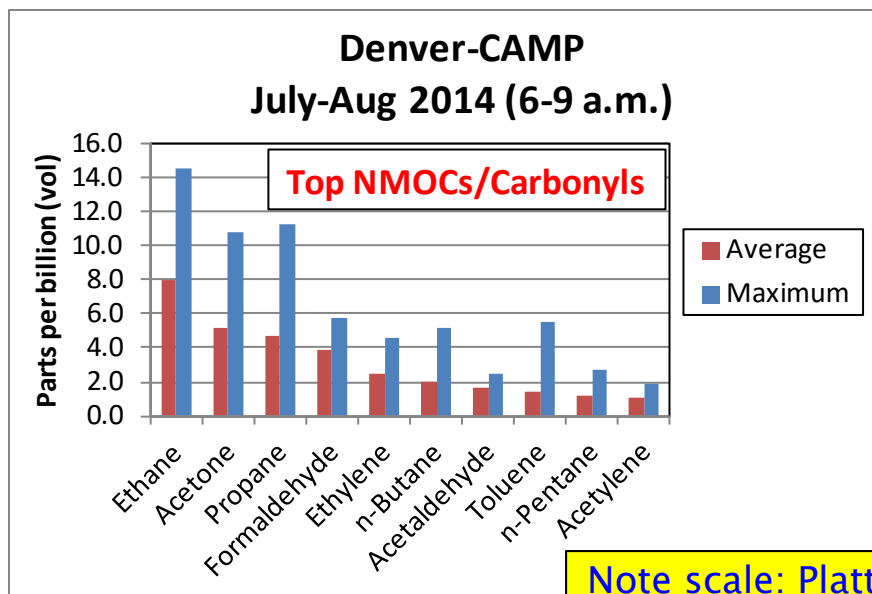
Trends over Time – CDPHE



CDPHE has seen a downward trend in ozone precursors over time

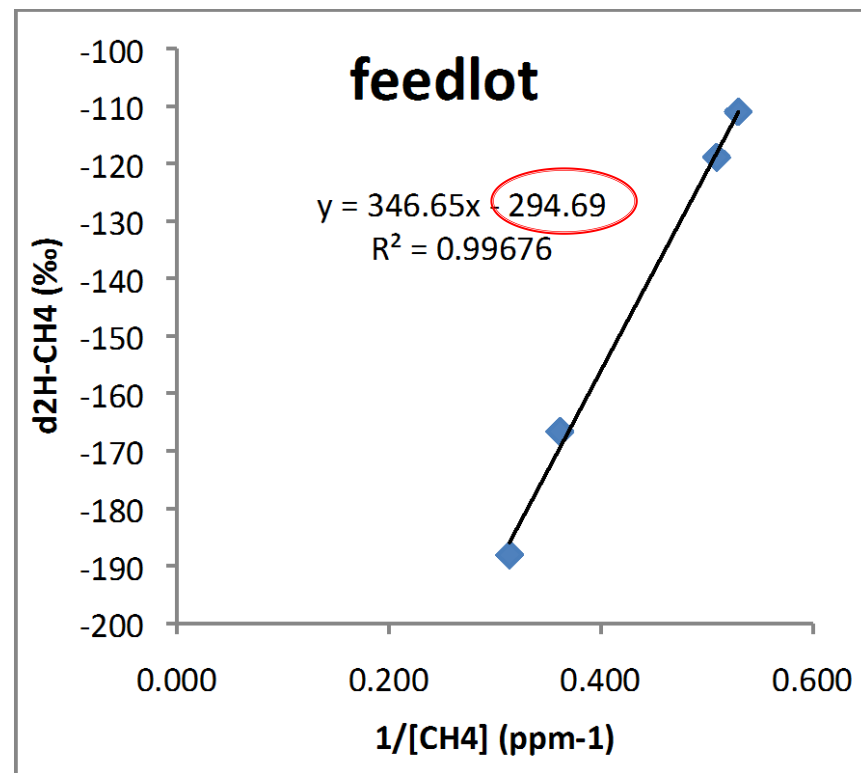
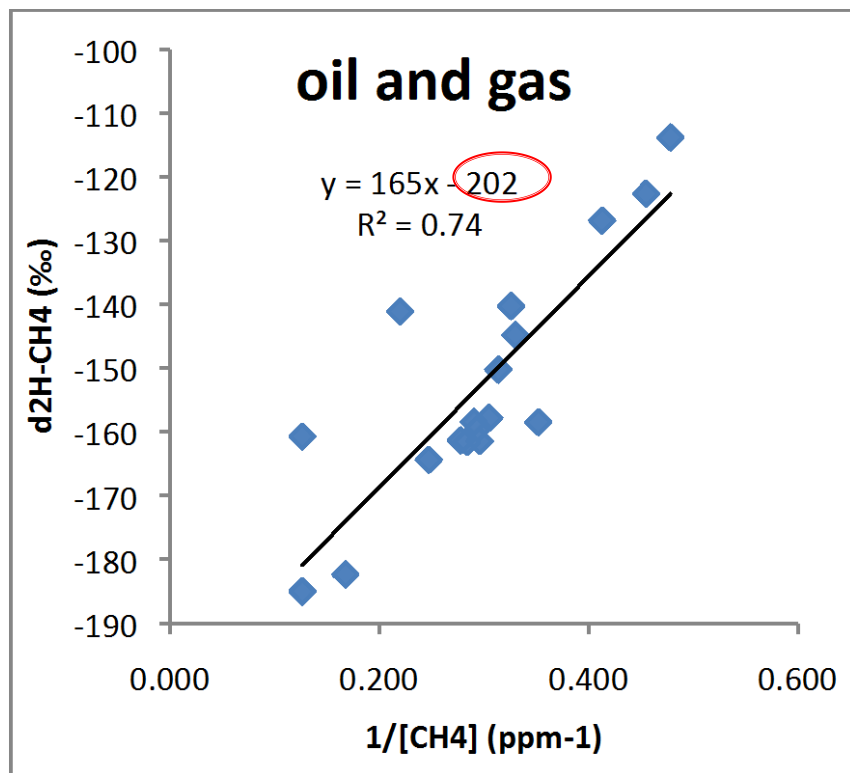
CDPHE (ground)

Top compounds during FRAPPE/DISCOVER-AQ



Ethane and propane (oil and gas) at or near the top for all sites

Canister Methane Isotope Analyses

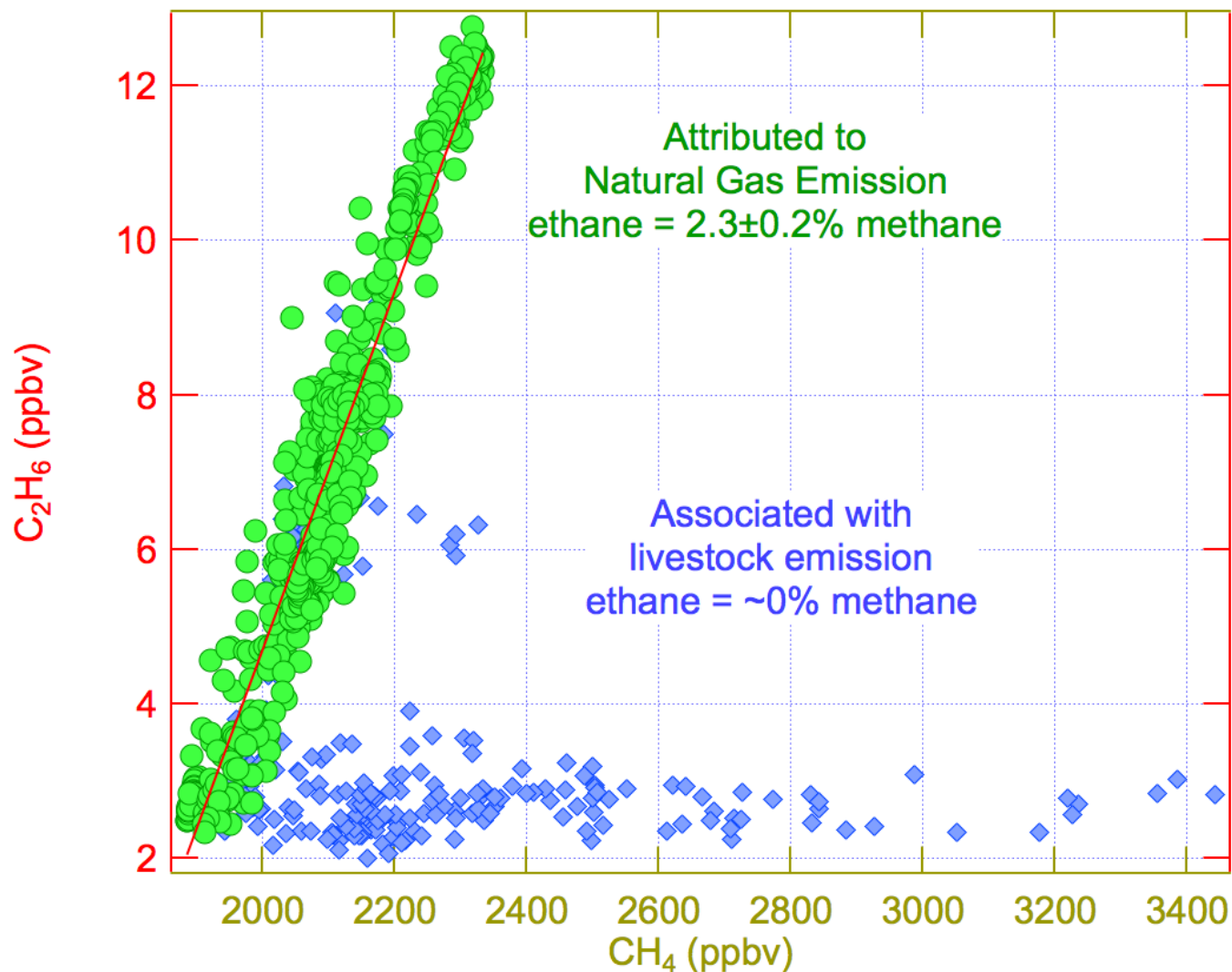


“Old” methane and “new” methane are isotopically distinct

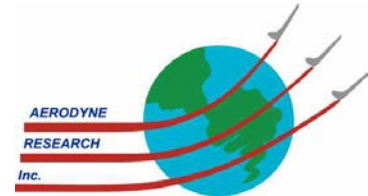
Oil and gas sources (“old”) have a $\delta^2\text{H}$ signature of approx. -200‰

Biogenic (landfill and feedlot) sources (“new”) have a $\delta^2\text{H}$ signature of approx. -290‰

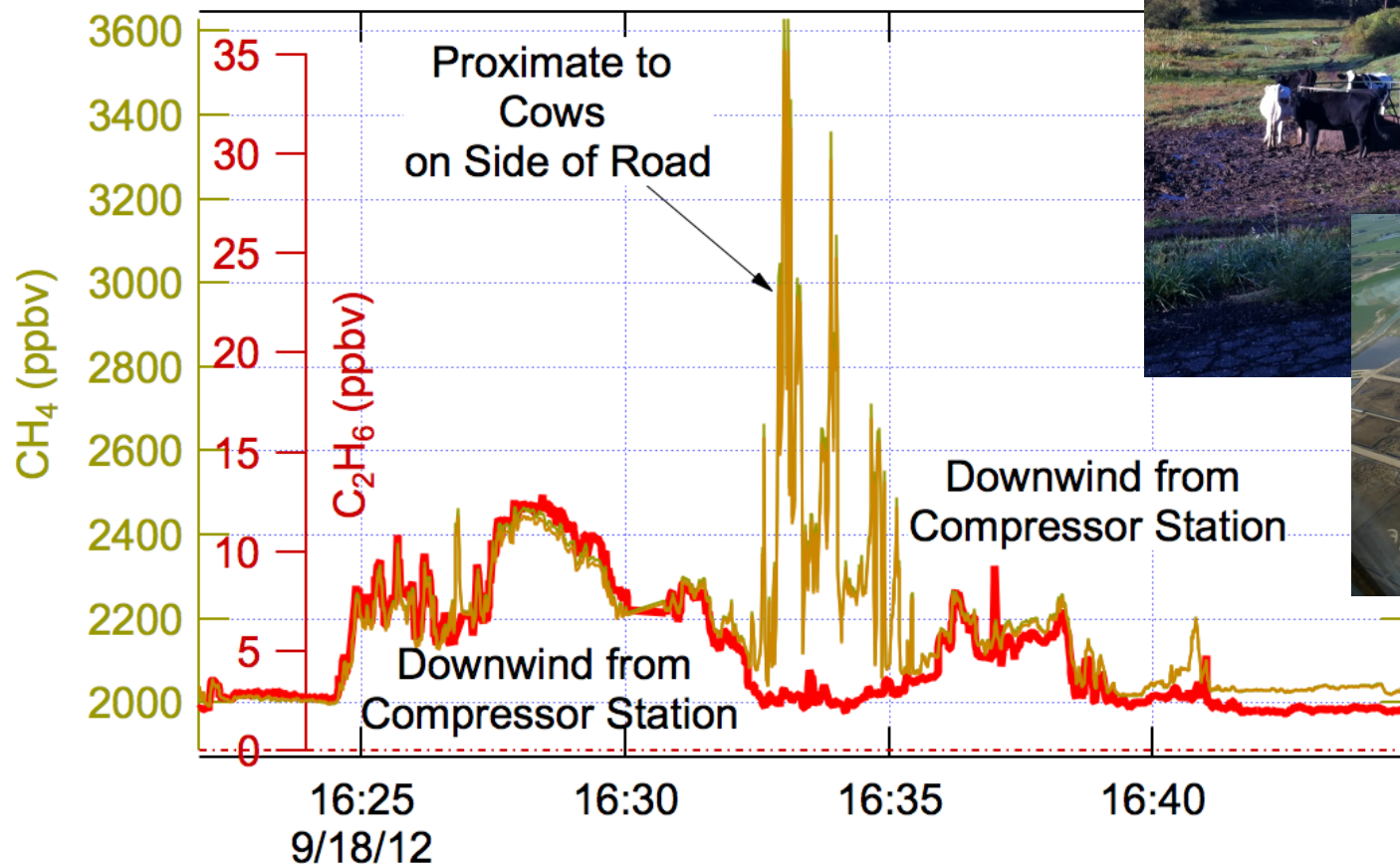
Ethane vs Methane Source Attribution



Mobile Lab Measurements

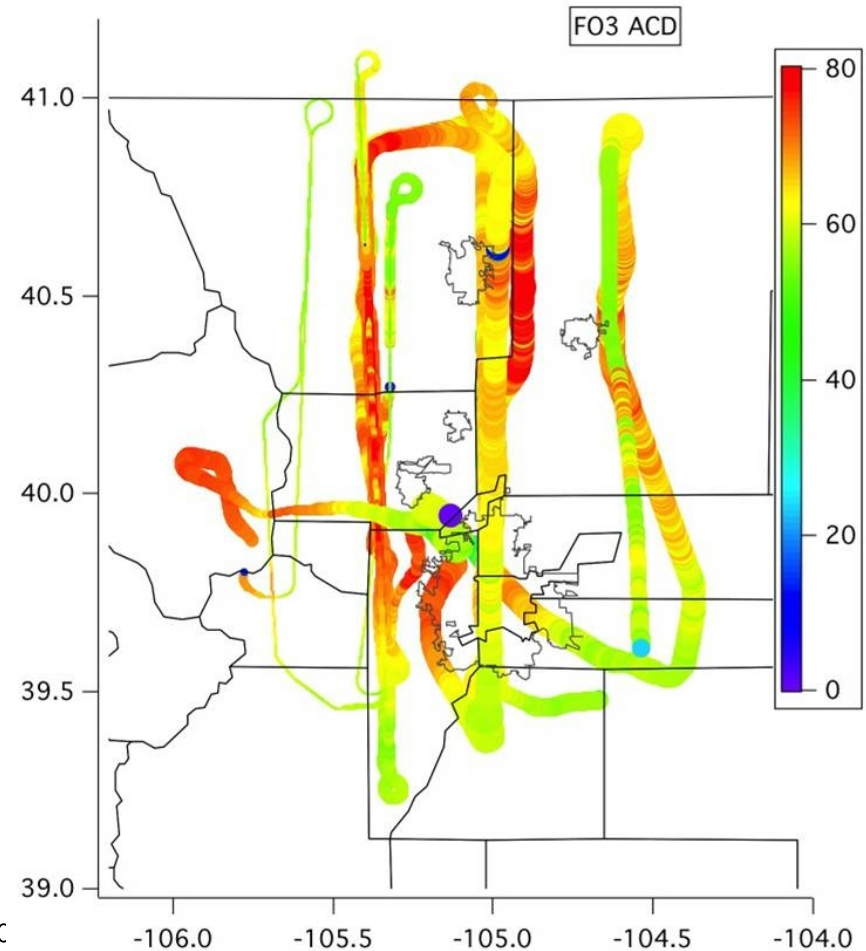
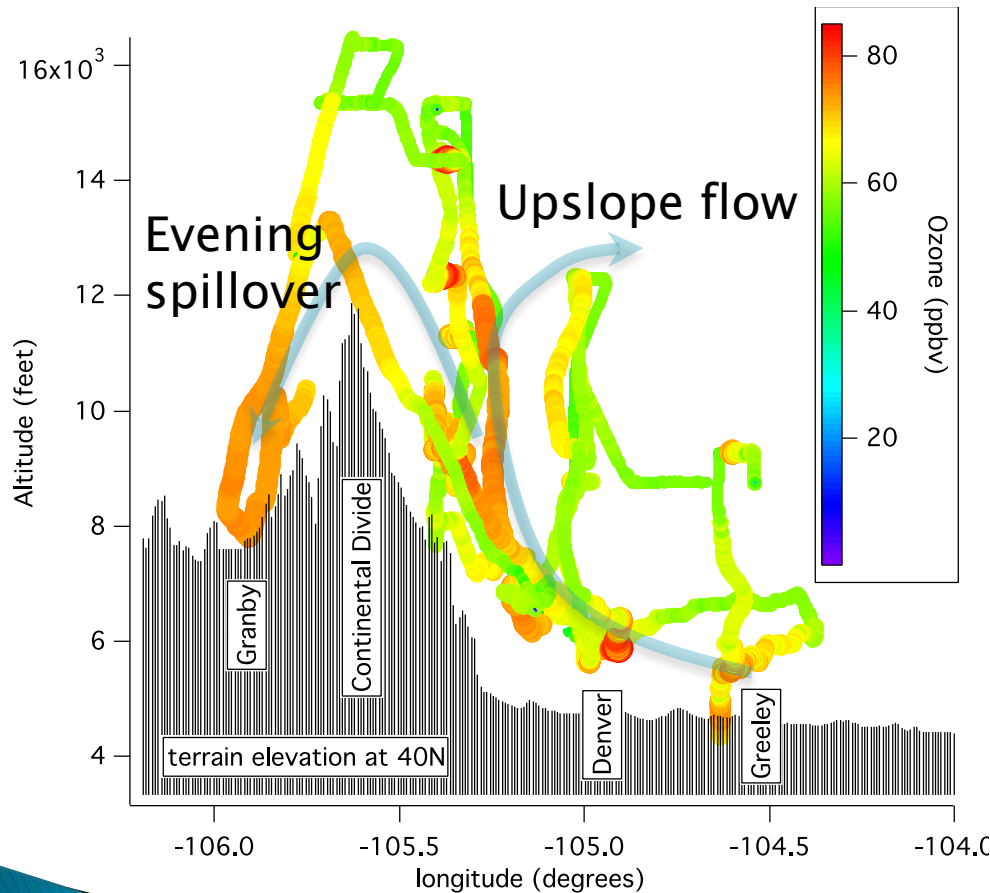


Source Attribution

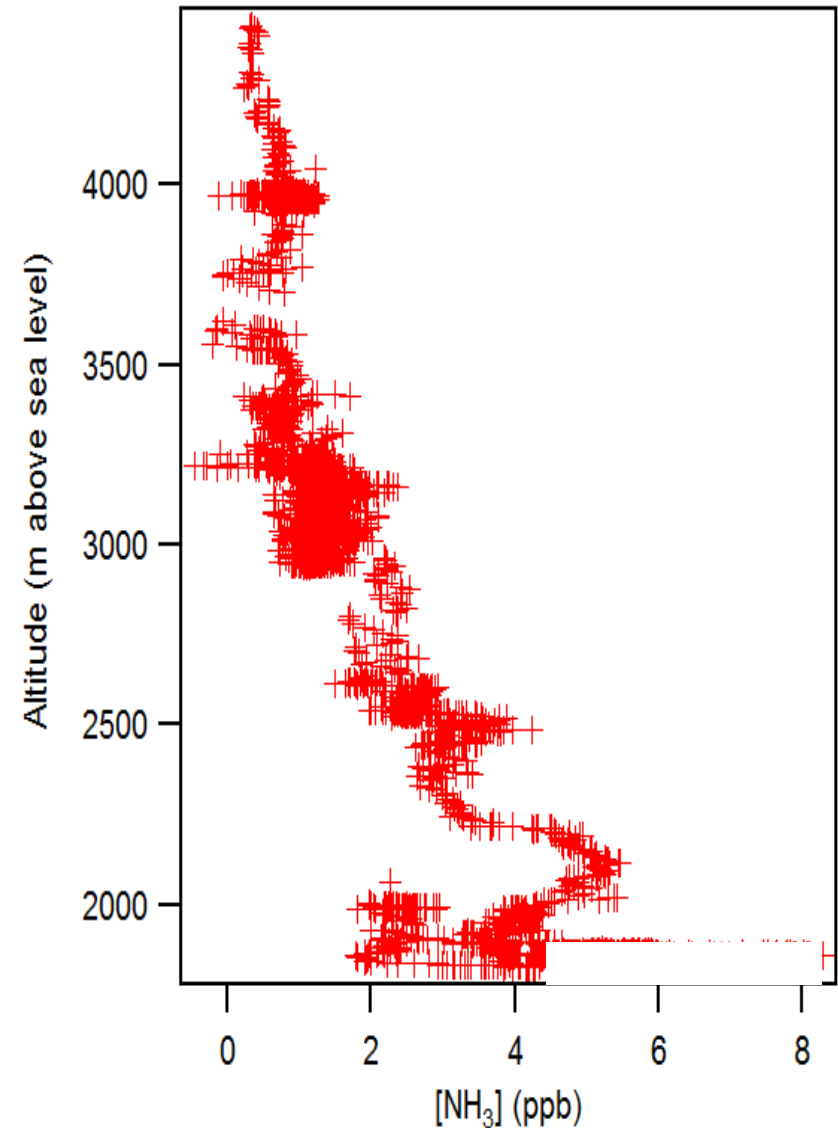
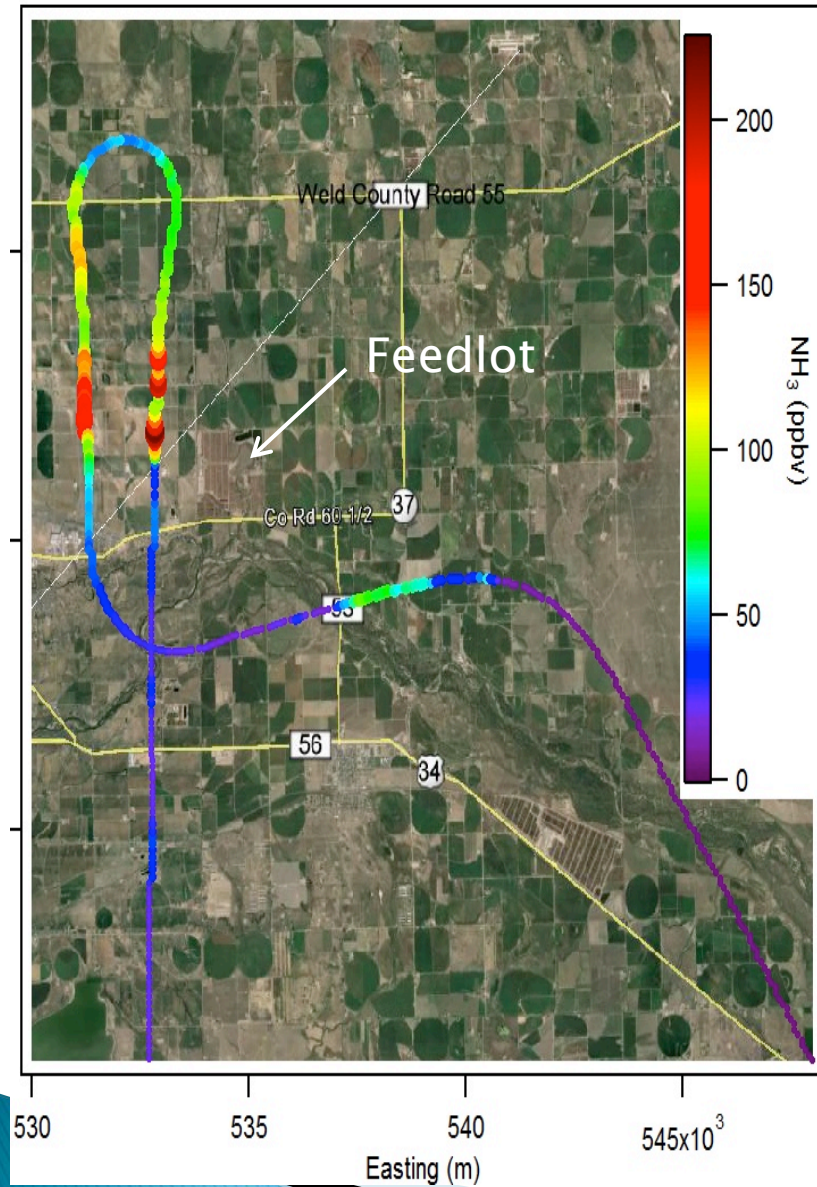


C-130 Ozone transport over the divide

Background ozone (50 ppb)



C-130 Ammonia in the Front Range



Preliminary Findings

- ▶ Identified and characterized many emission sources
- ▶ Northern Front Range region dominated by oil and gas extraction/ processing (DJ Basin) and agricultural emission signatures
- ▶ Urban center usually dominated by traffic and industrial emissions
- ▶ Air quality / ozone production and transport into foothills to west of Denver and to the continental divide dominated by Front Range emissions, not inflow from the west
- ▶ Influence of western slope sources on Front Range are small
- ▶ Outflow from Front Range into eastern plains and beyond can be significant
- ▶ Identified potential new / better monitoring locations
- ▶ Modeling (including chemistry) needs improvement

Current and Future Work

- ▶ NCAR is currently performing comprehensive analyses on the data from both studies
 - Chemical footprint analysis of FRAPPÉ & DISCOVER-AQ measurements and estimates of OH reactivity and contributions from local emission sources
 - Evaluation and improvement of chemical mechanisms commonly used in air quality models to correctly represent ozone formation potential for the various chemical regimes prevalent in the North Front Range area
 - Characterization of uncertainties in current emission inventories
 - Comprehensive evaluation of meteorological and chemical performance of regional air quality simulations
 - Sensitivity simulations for various emission control scenarios
- ▶ Universities and other participants are performing analyses and developing publications
- ▶ Analyses will be used to inform and help develop strategies for reducing ozone in the North Front Range of Colorado
 - What are the key emission sources?
 - What areas are NO_x limited vs VOC limited?
 - Are current emission reduction strategies working?
- ▶ NCAR would like to perform follow-up flights and measurements (funding-dependent)

Questions?



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