

# The 2014 Front Range Air Pollution & Photochemistry Experiment (FRAPPÉ) and Discover-AQ



**An overview for the USDA  
Agriculture Air Quality Task Force Meeting**

**December 4, 2014**



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**Colorado Department  
of Public Health  
and Environment**

# Overview



- **Overview of air quality concerns in Colorado**
- **FRAPPE and Discover-AQ campaigns**
  - Aircraft
  - Ground sites
  - Mobile Labs
  - Measurements with relevance to Agriculture
    - ✦ Methane
    - ✦ Ethane
    - ✦ Ammonia
- **Some Preliminary results**

# The Varied Sources of Air Pollution

- **Vehicles**

- On-road
- Off-road

- **Industry**

- Point
- Area

- **Agriculture**

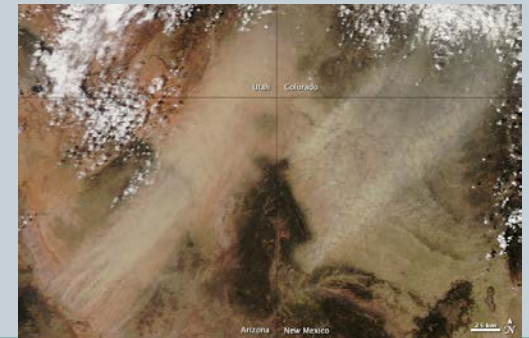
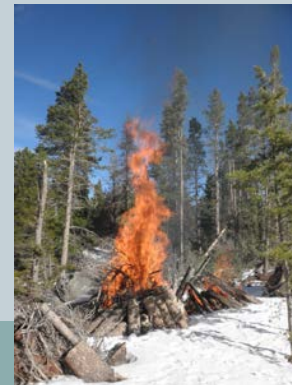
- **Household**

- Wood smoke
- Lawn equipment
- Paint and cleaning

- **Wildfires**

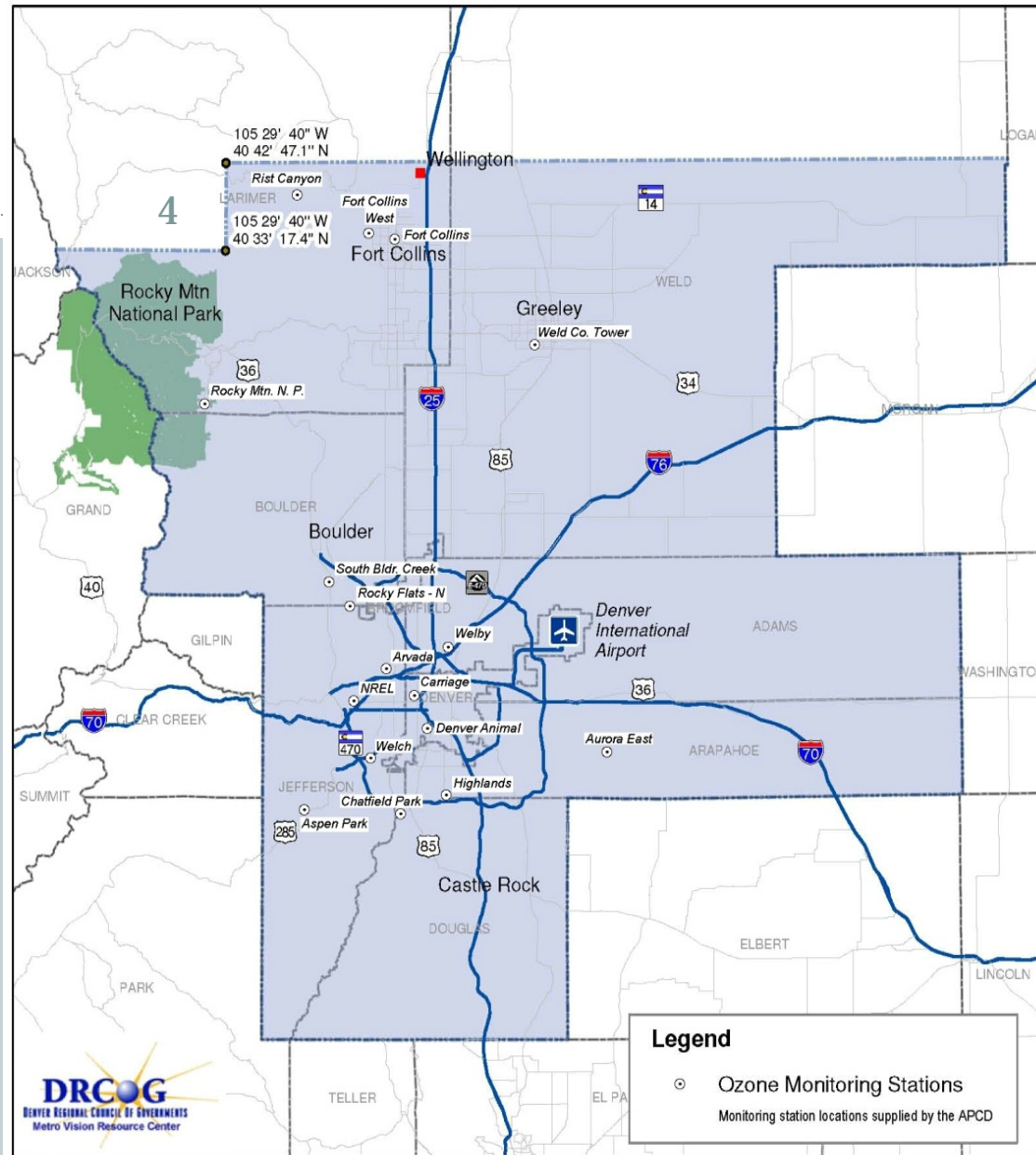
- **Blowing dust**

- **Others**



# Denver Metro/North Front Range Ozone Non- Attainment Area

- Colorado has rapid urban and industrial growth, complex terrain and meteorology, active photochemistry
- Ozone is of primary concern in Colorado



Denver-Boulder-Greeley-Fort Collins, Colorado  
Eight-Hour Ozone Control Area



# CDPHE Current & Emerging Air Quality Issues

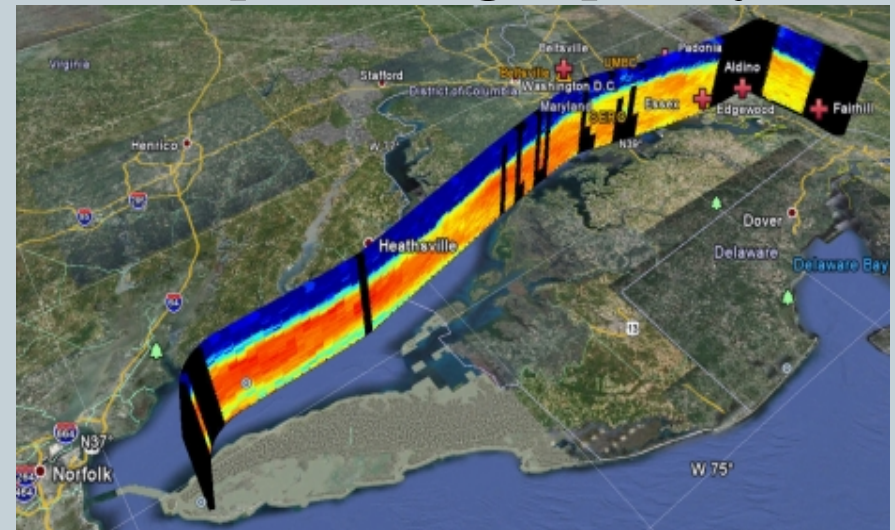


- **Non-attainment and maintenance areas**
- **Oil and gas emissions/emission inventories**
- **Greenhouse gas emissions**
- **Regional Haze**
- **Particulate Matter exceptional events**
- **Ozone in the Four Corners area**
- **West Slope particulate matter and ozone**
- **Rocky Mountain National Park nitrogen deposition**

# What is an Air Quality Field Study?



- Non-operational (duration ~weeks/months )
- Research-grade instruments
- Basic Science or targeted goals
- Provides a comprehensive snapshot of local and regional conditions during the study
- Intensive—highly concentrated, frequent, high quality contributions from:
  - ground sites
  - mobile laboratories
  - sondes and balloons
  - aircraft measurements
  - modeling
  - satellite measurements



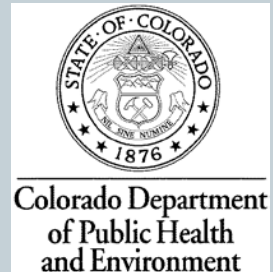
Discover-AQ flight track for Baltimore

# Front Range Air Quality Studies



- Two simultaneous major research field campaigns occurred in Colorado from **July 15-August 15, 2014**
  - FRAPPÉ (NCAR)
  - DISCOVER-AQ (NASA)
- Overlap with Other Studies
  - Oil and Gas Dispersion Study (CSU via CDPHE funding)
  - Ag Early Warning Pilot
  - Ongoing Efforts from CSU, CU, NOAA

## Major funding agencies:



## Partners:

EPA, NOAA, NPS, RAQC & others



# Front Range Study Goals



FRAPPÉ & Discover-AQ will increase understanding of:

- Ozone (formation, transport, modeling)
- Emissions (**VOCs**, **NO<sub>x</sub>**, **ammonia**, **SO<sub>2</sub>**, etc.) across all sectors
- Nitrogen cycling in the atmosphere
- Pollutant transport within, into and out of Colorado
- Sources of pollution and **methane**, an important greenhouse gas

It will also improve our:

- Air quality forecasting
- Air quality modeling in Colorado's complex topography

# FRAPPÉ

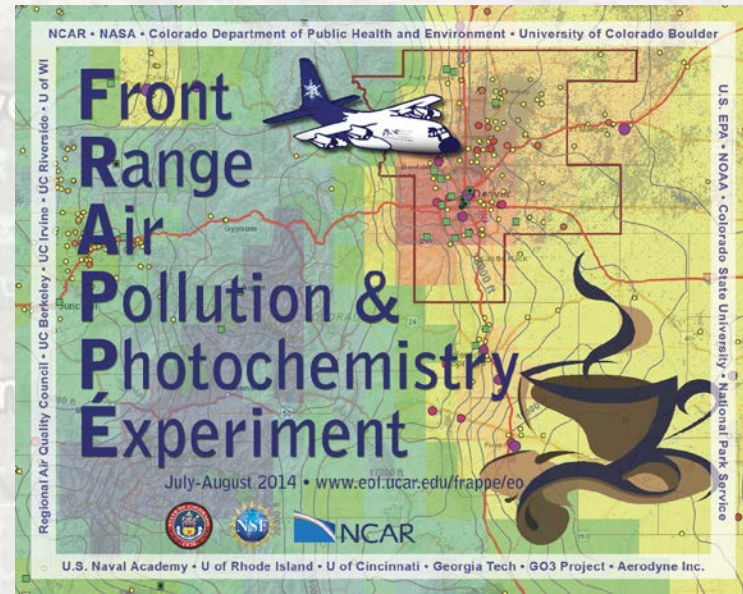
- Organized by NCAR
- C-130 aircraft, 12-15 flights
- Continuous measurements
  - ground
  - aircraft
  - mobile labs
- Comprehensive AQ & Met sampling, modeling, forecasts

## 6 Major Ground Sites (joint with Discover-AQ)

Ft. Collins West  
BAO Tower (Erie)  
Platteville  
Downtown Denver  
NREL  
Chatfield Park



& additional ground sites



# 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
- on C-130 CDPHE funded:
  - ethane, formaldehyde
  - VOCs (canisters)
  - ammonia
  - aerosol measurements
  - NO<sub>x</sub>/NO<sub>y</sub> measurements
  - SO<sub>2</sub>



# DISCOVER-AQ

Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality



- Goal: Improve satellite capability to interpret AQ conditions near the surface ( $\text{NO}_2$ ,  $\text{NH}_3$ , formaldehyde,  $\text{CO}$ ,  $\text{O}_3$ , particles).
- 4 Regions: Baltimore (2011), San Joaquin Valley (2013) Houston (2013), Colorado Front Range (2014)
- 2 Aircraft (12-15 flights each)
- Ground measurements  
(6 major sites tied in with CDPHE sites)
- Connects satellite measurements with ground observation networks, other research efforts



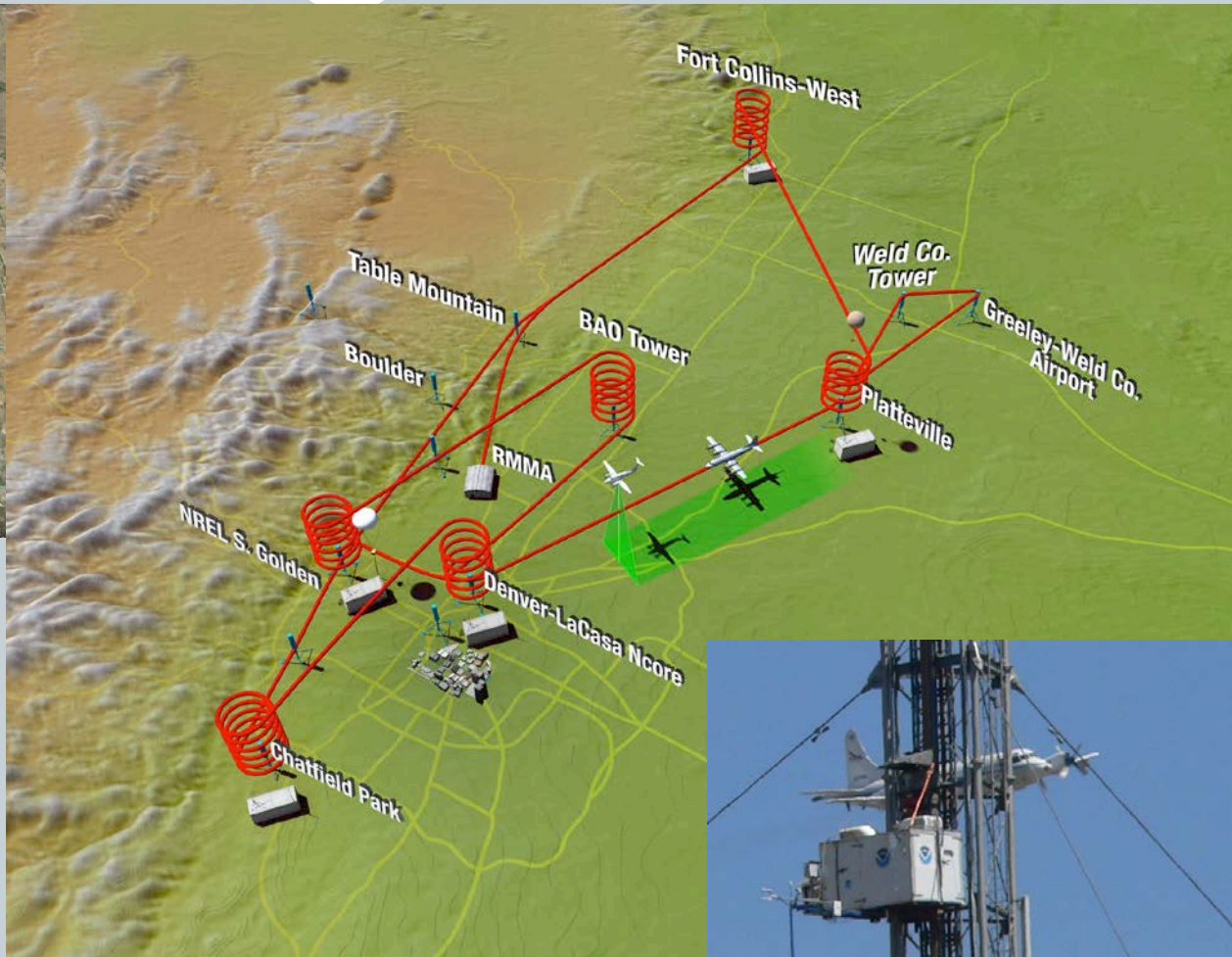
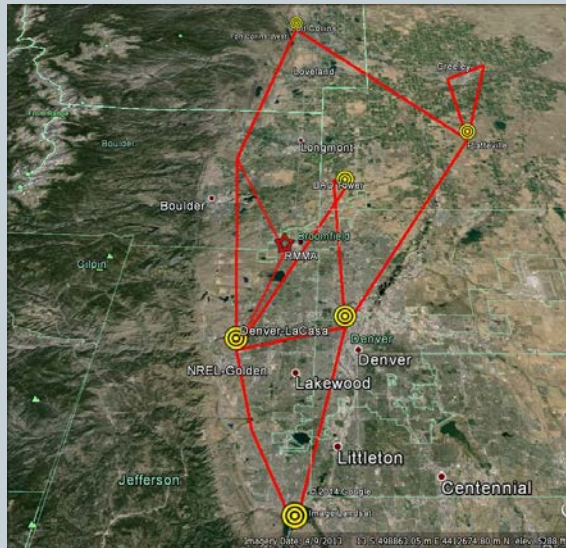
King Air twin engine turbo prop (LIDAR)



P-3 (full AQ instrumentation suite)



# DISCOVER-AQ



- Fixed Flight Plan
- Spirals will be flown over 6 ground sites, 3 times/flight day
- In-situ & upward-looking instruments, satellites and aircraft instruments will complement each other

Photo: Andy Langford (NOAA)

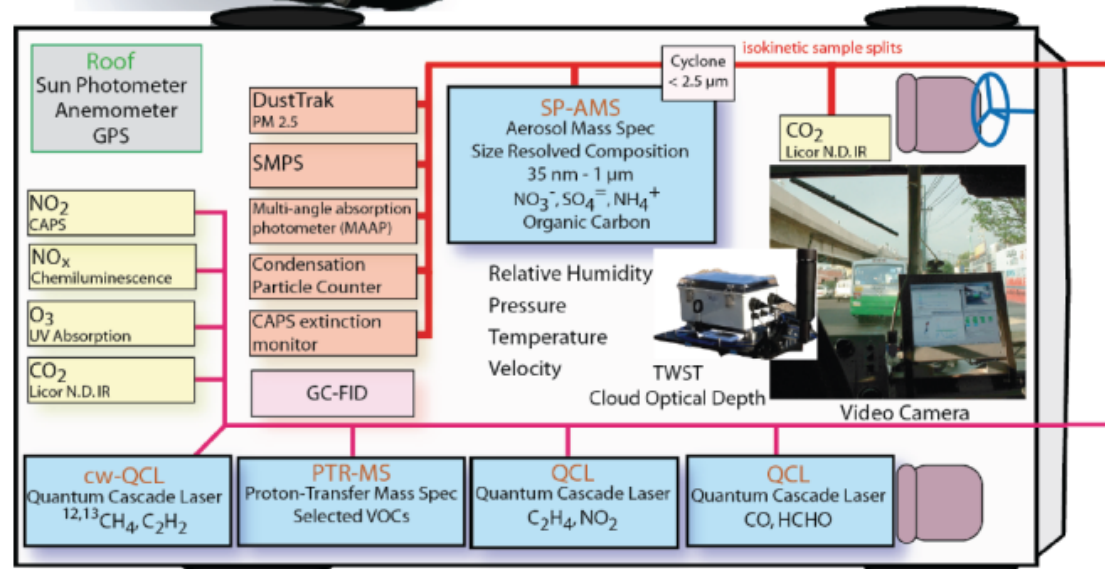
# Field Study Mobile Labs



- Aerodyne mobile lab instrumented similarly to aircraft
- Can get near sources, operate on-road
- Additional mobile labs were operated by NOAA, NPS and researchers from several universities



Aerodyne Mobile Lab  
DISCOVER-AQ, 2013



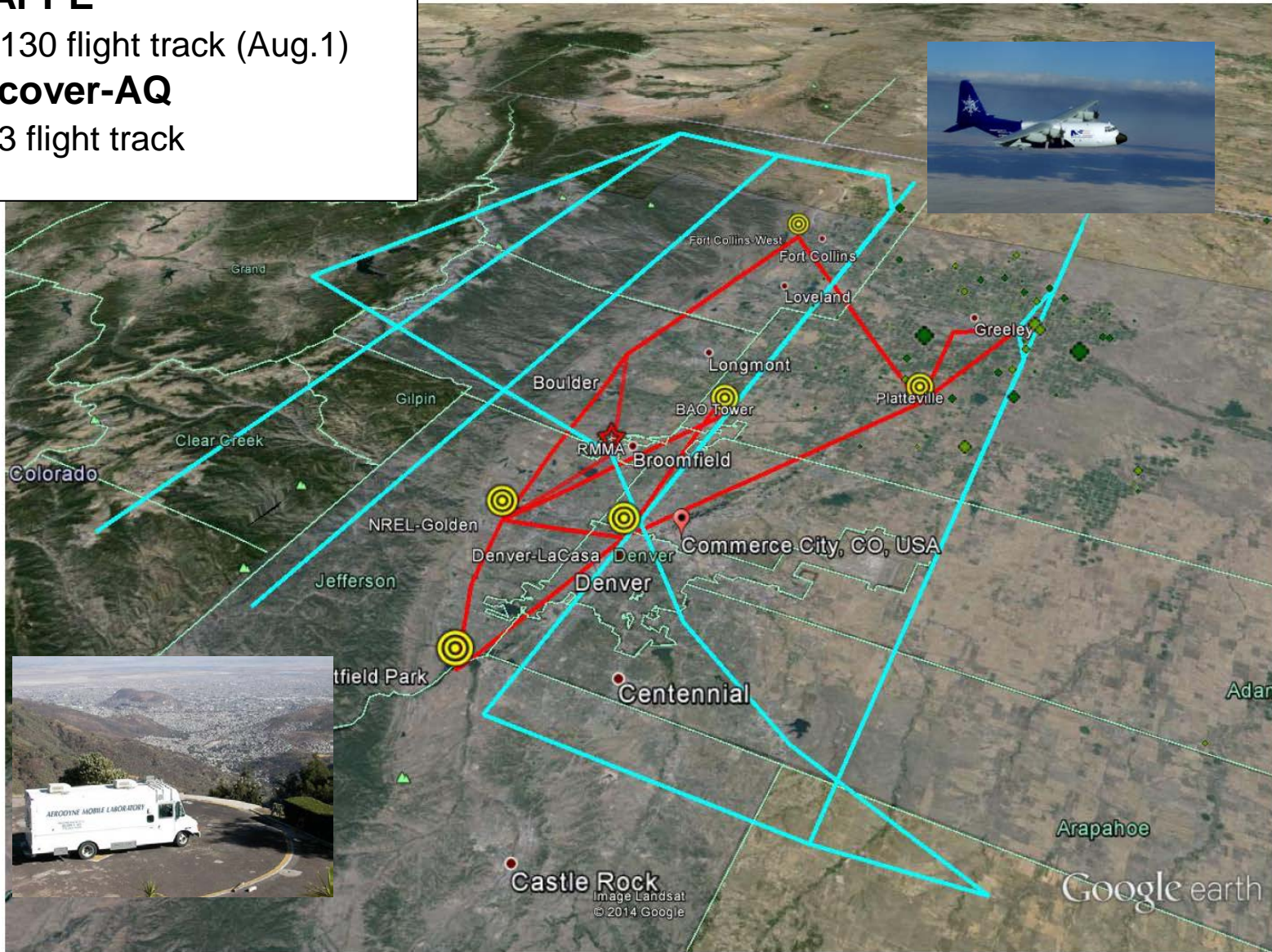
Source: Aerodyne, Inc.

# FRAPPE

— C-130 flight track (Aug. 1)

**Discover-AQ**

— P-3 flight track



Google earth

miles  
km



# Other Collaborators and Efforts



- CDPHE installed additional ground ozone sites
- NPS operated a ground site near Long's Peak Ranger Station
- EPA provided ~6 NO<sub>x</sub> instruments which were co-located with CDPHE sites
- EPA added many “next-generation” small sensors for ozone
- 3 ozone LIDARs (funded by NASA)
- Modeling and Forecasts by CDPHE, NASA, NCAR, EPA, etc.
- NOAA: mobile labs, Erie tower site, wind profilers, ozone LIDAR
- CU/CIRES and CSU/CIRA researchers have received grants
- Ball Aerospace
- DOE Oil & Gas Study (joint with NOAA)
- Others



# What makes this study unique?



- First Major front range AQ study in decades, with modern instrumentation
- Interagency cooperation and funding
- Comprehensive air measurements of particles, gas phase, meteorology, satellite instruments, etc.
- Extensive, highly detailed modeling of Front Range with multiple tracers
- Multiple, high time resolution measurements of **ammonia, ethane, methane** from multiple platforms

# Data Archive



## FRAPPE/Discover-AQ Data

- Ongoing process of being compiled, validated, cross-checked, QA/QC, etc.
- **All data shown here are PRELIMINARY**
- Data will be published at NASA's site
- Final Data Due Jan. 2015
- First science meeting will be in Boulder in May, 2015.

Airborne Science Data  
for Atmospheric Composition

Home Tools Missions Data Contact Us

**DISCOVERAQ/FRAPPE/CO\_2014**  
Current Archive Status  
As of Thu Sep 4 12:21:12 2014 EST

✓ Login succeeded -- http download is ON.

P-3B Aircraft	B200 Aircraft	NCAR C130 Aircraft	Merges	Model
Analysis	Satellite	Sondes	BAO Tower *	Chatfield Park *
Denver-LaCasa Ncore*	Fort Collins-West *	NREL-Golden *	Platteville *	Aurora East *
Boulder *	CAMP *	I-25 Denver *	Niwot Ridge *	Rocky Flats - N *
Squaw Mountain *	Table Mountain *	Welch *	Weld Co. Tower *	Greeley-Weld Airport*
Parkland Airport *	Ground-Mobile	Ground-Other	DeTect Wind Profiler	P-3B Aircraft Videos

\* Ground Site

Current list for the MERGES Data:

Permanent Data Archive:

<http://www-air.larc.nasa.gov/missions/discover-aq/discover-aq.html>

# FRAPPÉ: Relevance to Agriculture in Colorado

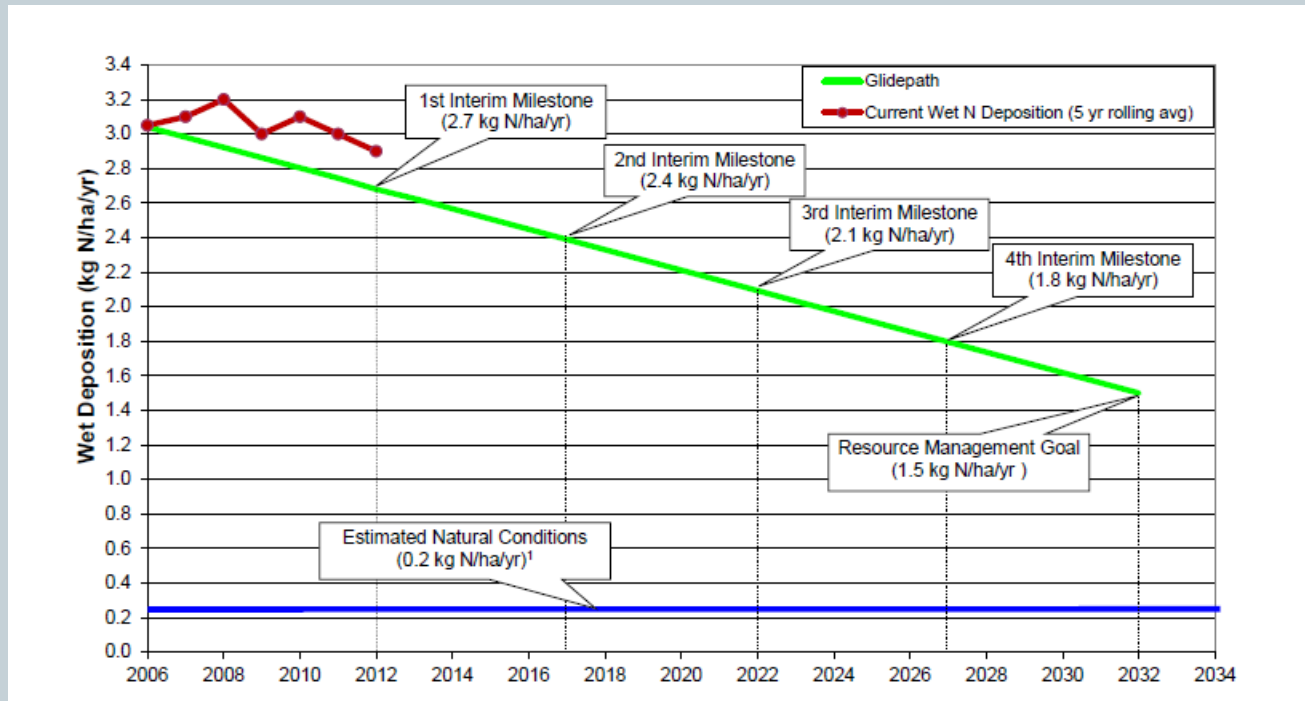


- FRAPPÉ will help answer questions about
  - emissions inventories
  - pollution transport and photochemistry
- Campaigns dovetail with:
  - RNMP initiative
  - Ag early warning system
  - Many other research efforts in Colorado
- FRAPPÉ and Discover-AQ provide data on characteristic emissions across sectors and industries
- Complex air quality problems require cooperative solutions  
(e.g. RMNP initiative, O&G cooperative rulemaking, etc.)
- **Air quality concerns from Agriculture are mainly methane and nitrogen**

# Nitrogen Deposition: RMNP Initiative



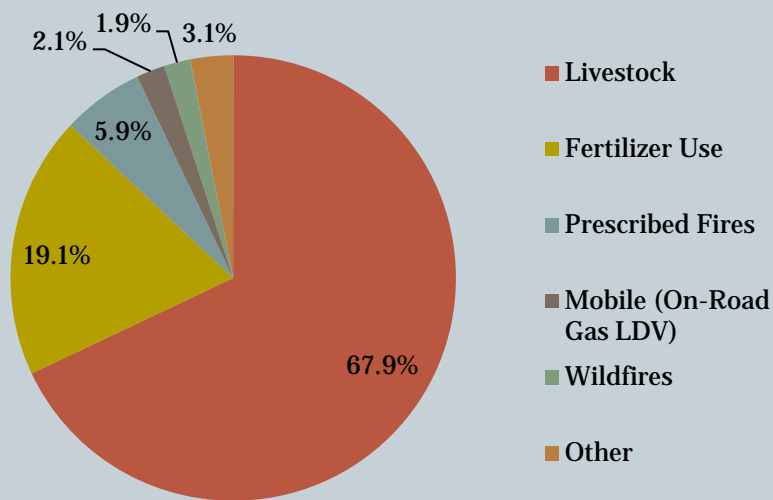
- MOU agencies (CDPHE, NPS, and U.S. EPA) issued the Nitrogen Deposition Reduction Plan (NDRP) in 2007



<https://www.colorado.gov/cdphe/rocky-mountain-national-park-initiative>

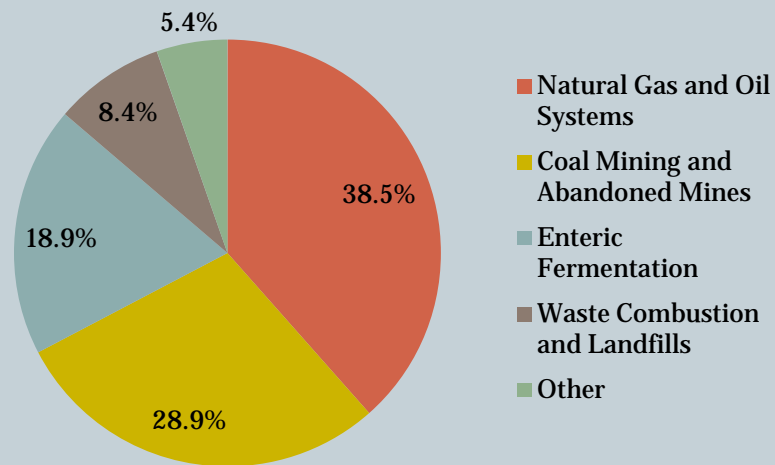
# Colorado Ammonia and Methane Emissions

## Ammonia (2011 NEI)



Total ~79 k tons  
(30% from 9 county  
NAA)

## Methane (CDPHE 2010 GHG inventory)



Total ~1.2 M tons

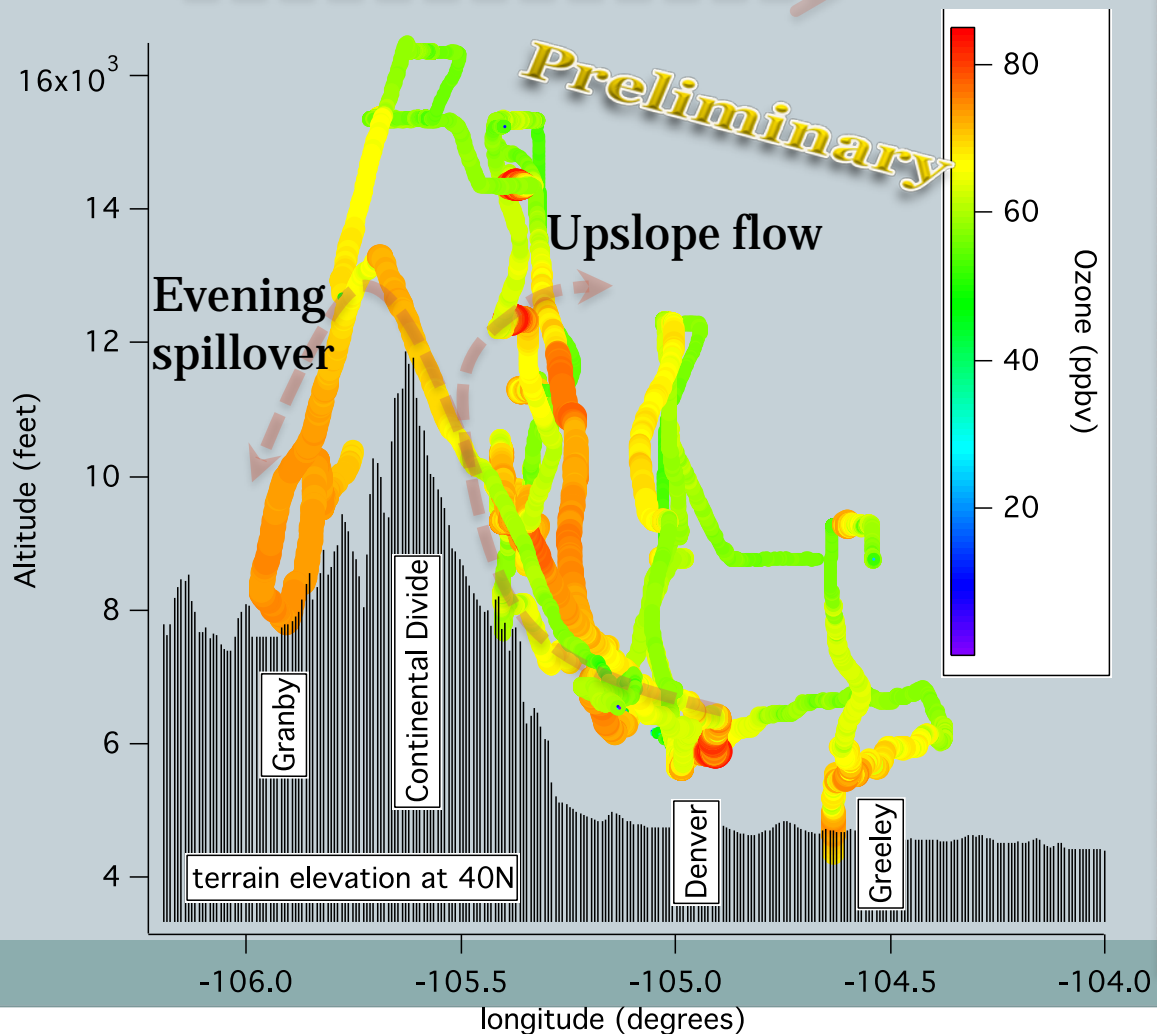
Also important for N deposition:

NO<sub>x</sub> Total ~308 k tons (40% from 9 county NAA)



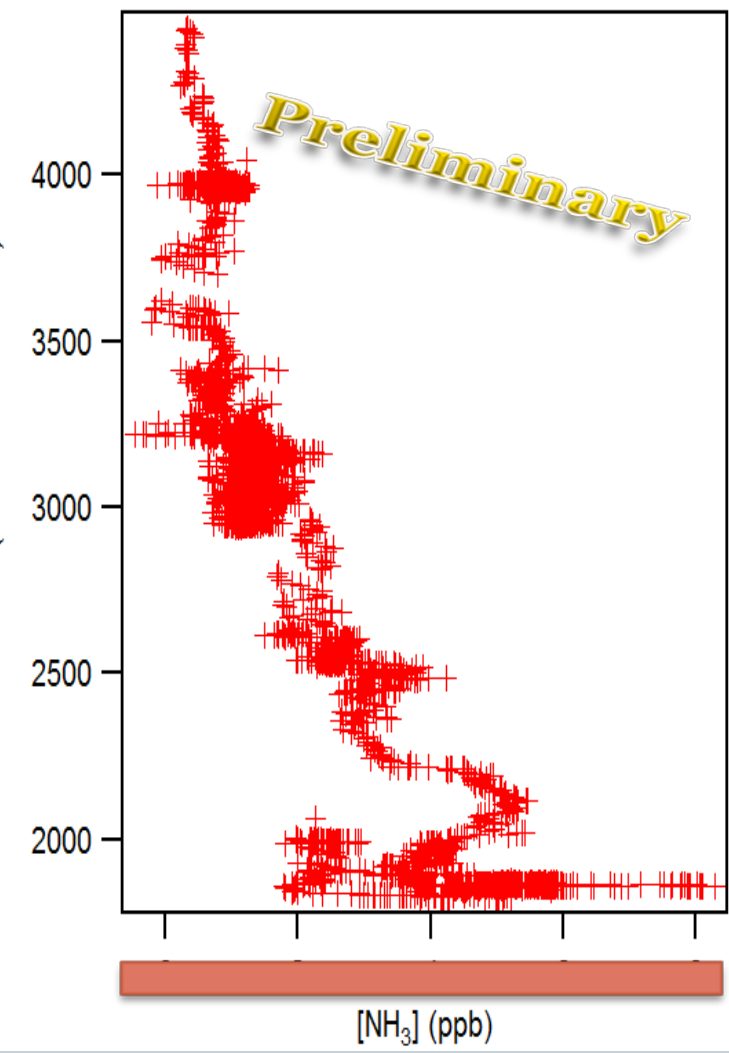
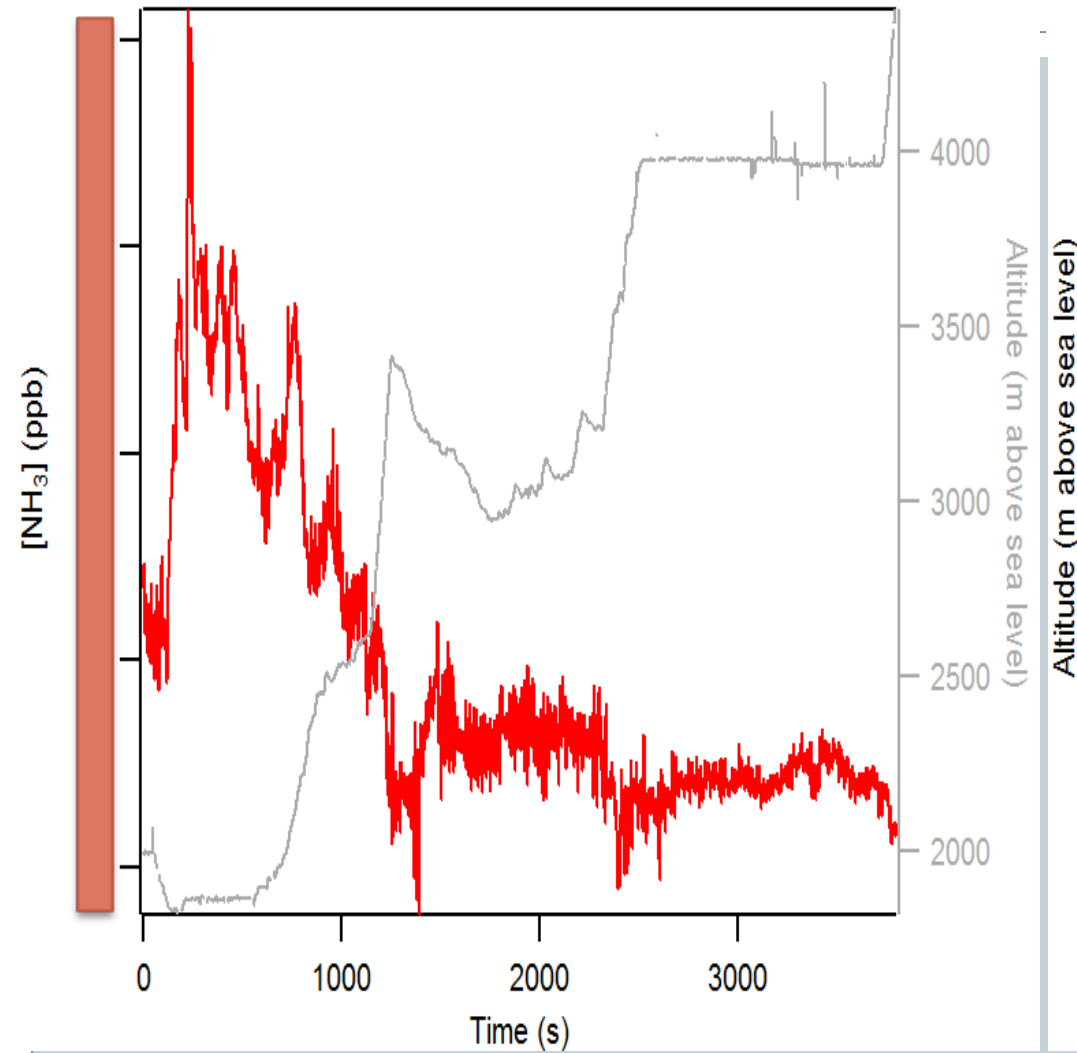
## Front Range Air Pollution and Photochemistry Experiment (FRAPPÉ) First results from C-130 flights July 17-August 18, 2014.

Background ozone (50 ppb) →



*The Figure highlights a transport event of ozone, produced over the Front Range urban areas, being pushed westward into the mountains by thermally driven upslope. The flight included a low approach into Granby Airport, located west of the Continental Divide in the Fraser Valley. The measurements clearly show how Front Range ozone can impact remote areas up to the divide and into the adjacent valleys on the west side of the divide.*

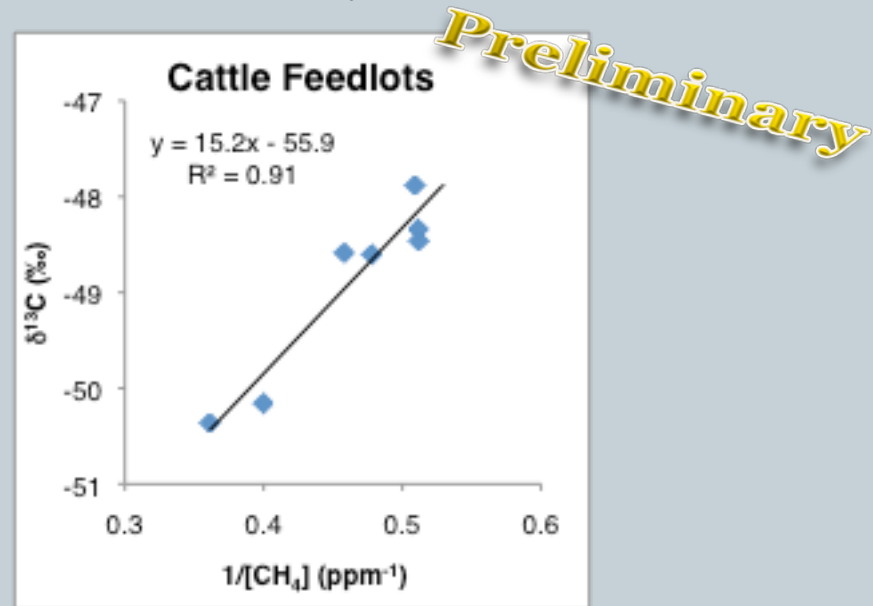
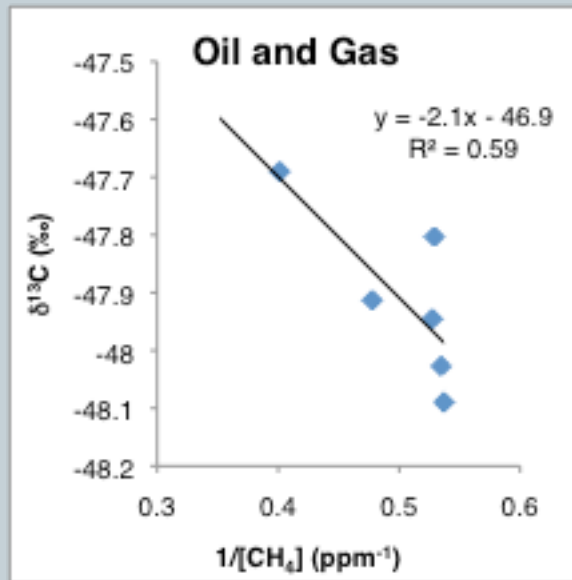
# Ammonia above the Front Range



# Canister Methane Isotope Analyses



Preliminary results from University of Cincinnati-University of California, Irvine

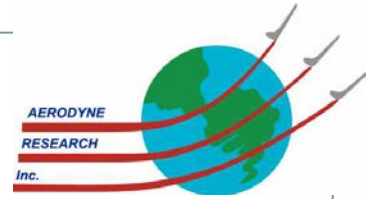


As expected, methane from biological and thermogenic sources is isotopically distinct (-55.9‰ versus -46.9‰)

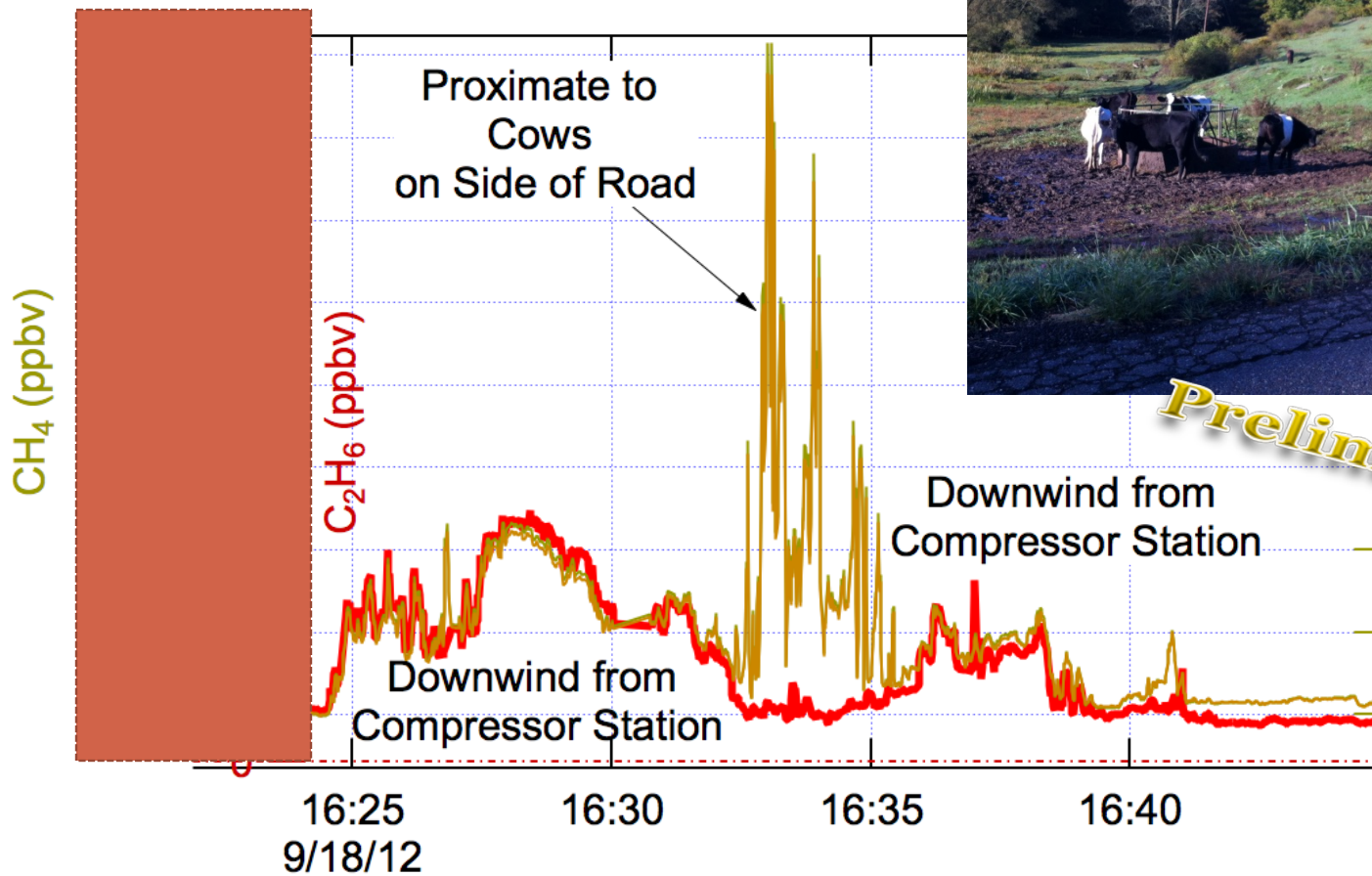
More samples (including landfill and other CH<sub>4</sub> sources and aircraft samples) to come, as well as  $\delta^2H-CH_4$  analyses



# Mobile Lab Measurements

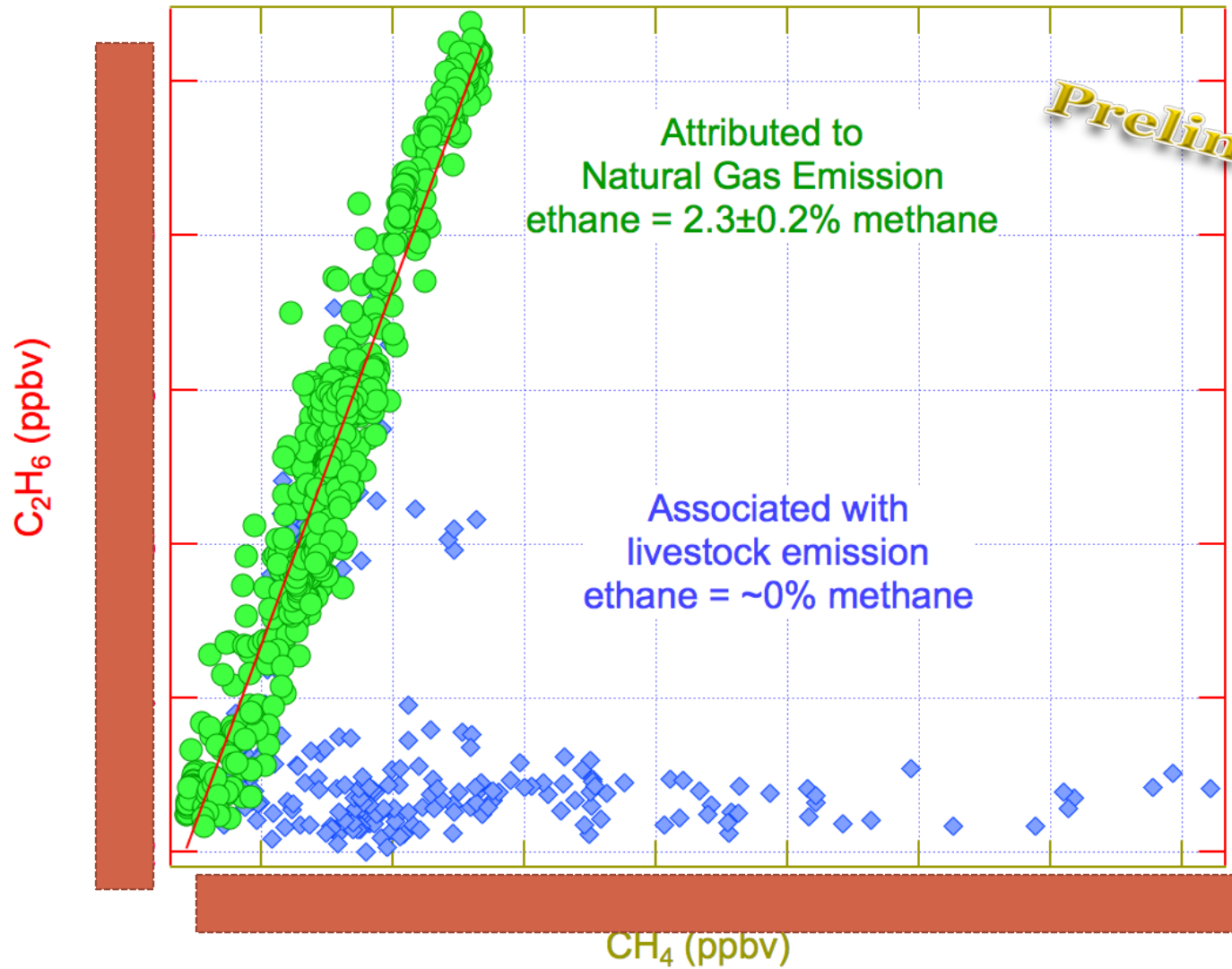


## Source Attribution



*Preliminary*

# Ethane measurement assists methane source attribution



*Preliminary*

# Some Very Preliminary Findings



- Clearly identified and characterized all emission sources
- Northern FR region (DJ Basin) dominated by oil and gas extraction / processing and agricultural emission signatures
- Urban center usually dominated by traffic and industrial emissions
- Ozone efficiently formed across the region
- Emissions can sometimes stay regionally separated
- In the absence of wildfires, this summer's Front Range air quality was controlled by local emissions, not large scale inflow
- Air quality / ozone production and transport in(to) eastern foothills and to the continental divide dominated by FR emissions, not inflow from the west
- Influence of western slope sources on front range are small
- Outflow from FR into eastern plains can be significant (not shown)
- Identified potential new / better monitoring locations

# More information



- **FRAPPÉ:**

Science: <https://www2.acd.ucar.edu/frappe>

Public Outreach: <https://www.eol.ucar.edu/frappe/eo>

Principle Investigators: Frank Flocke, [ffl@ucar.edu](mailto:ffl@ucar.edu) & Gabi Pfister, [pfister@ucar.edu](mailto:pfister@ucar.edu)

- **DISCOVER-AQ:**

[http://www.nasa.gov/mission\\_pages/discover-aq/](http://www.nasa.gov/mission_pages/discover-aq/)

- **CDPHE Contacts and Other Questions:**

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