SURFACE OZONE IN THE NORTHERN FRONT RANGE AND THE INFLUENCE OF OIL AND GAS DEVELOPMENT ON OZONE PRODUCTION DURING FRAPPE/DISCOVER-AQ

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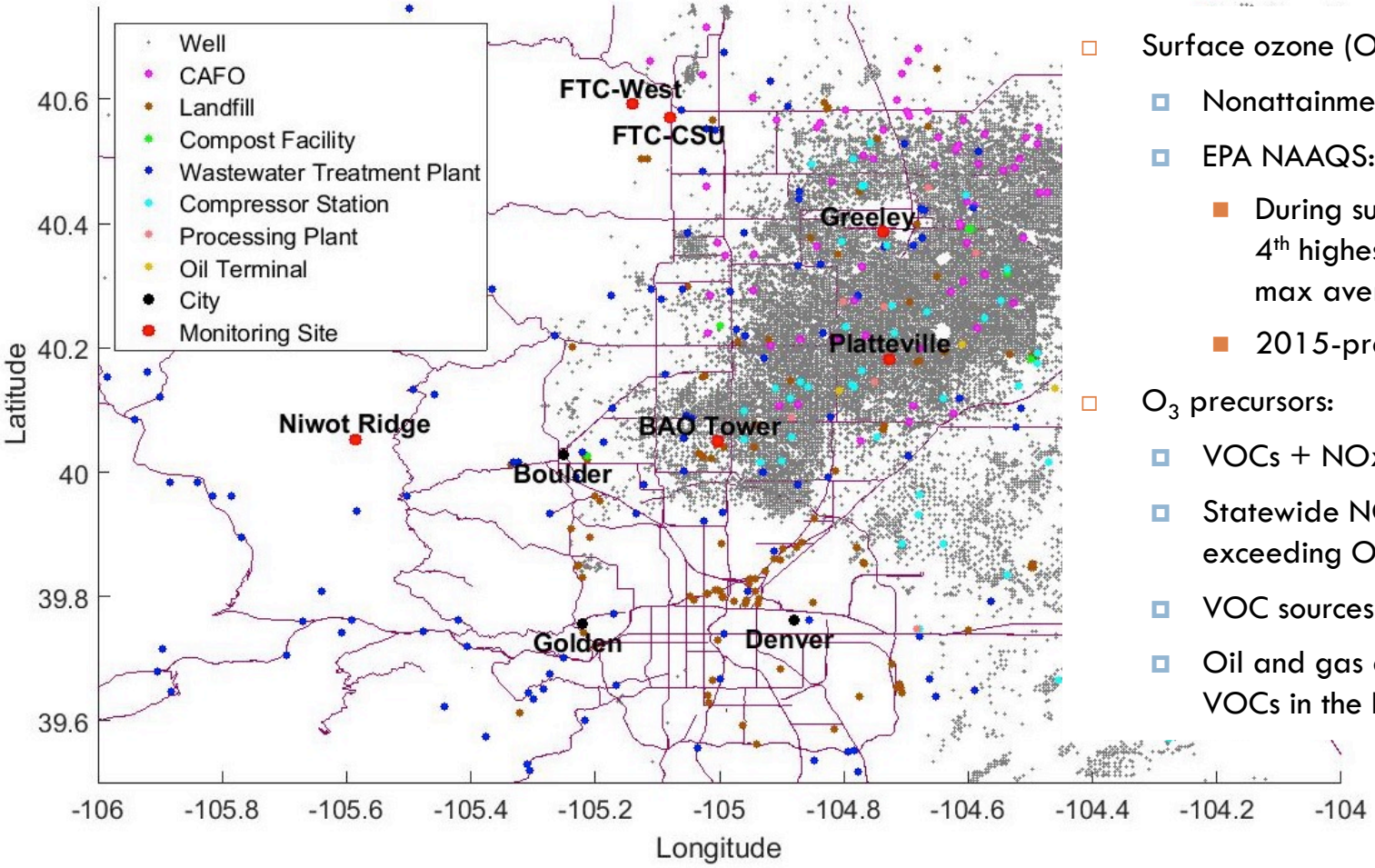
Overview

- Surface ozone (O_3) in Front Range
  - Motivations
  - "Background" O_3 from surface sites
  - Summer 2014 O_3 summary
  - Spatial variability at surface sites
- Case studies
  - Three days
  - Mobile lab drives
  - Surface monitoring stations
  - Discrete air samples in flasks

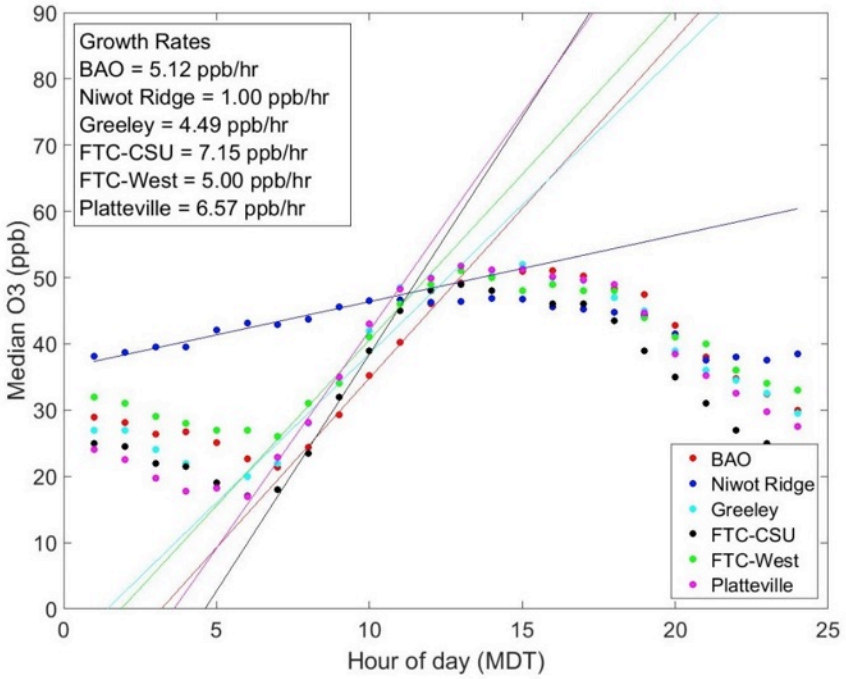
Motivations



- Surface ozone (O_3) in Front Range
  - Nonattainment area since 2007
  - EPA NAAQS:
    - During summer 2014: 75 ppb for 4th highest 8-hr average daily max averaged over 3 years
    - 2015-present: 70 ppb
- O_3 precursors:
  - VOCs + NOx + sunlight = O_3
  - Statewide NOx reductions but still exceeding O_3 standard
  - VOC sources play a role
  - Oil and gas activities major source of VOCs in the Front Range

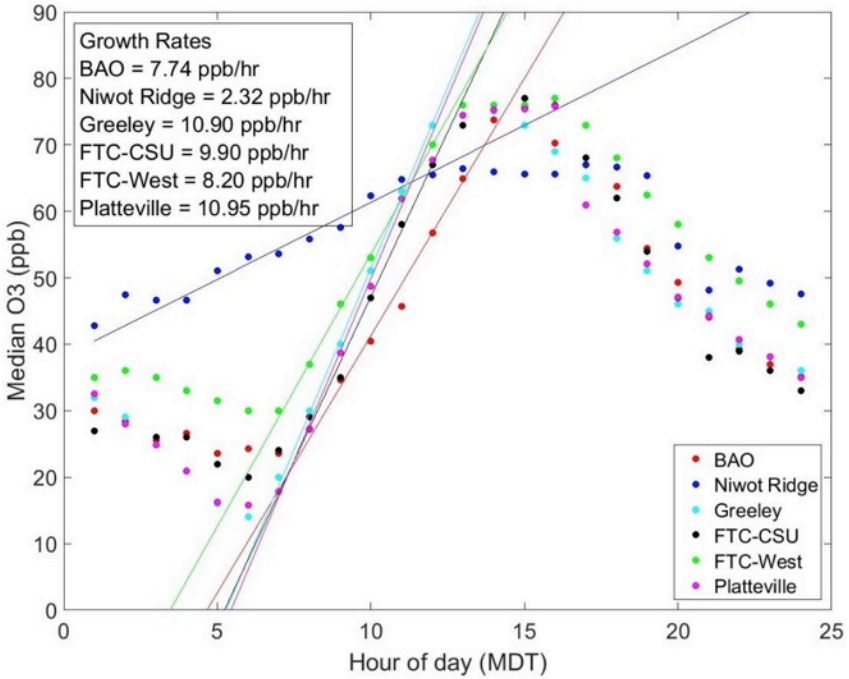
"Background" O_3

- Estimated underlying O_3 distribution on days without significant photochemical production to be 45-50 ppb
- Used long-term data from Niwot Ridge on days without significant upslope events



Days w/ peak O_3 <60 ppb
(Jun-Aug 2013-2015)

~35% of days in Front Range, 56% of days at Niwot Ridge

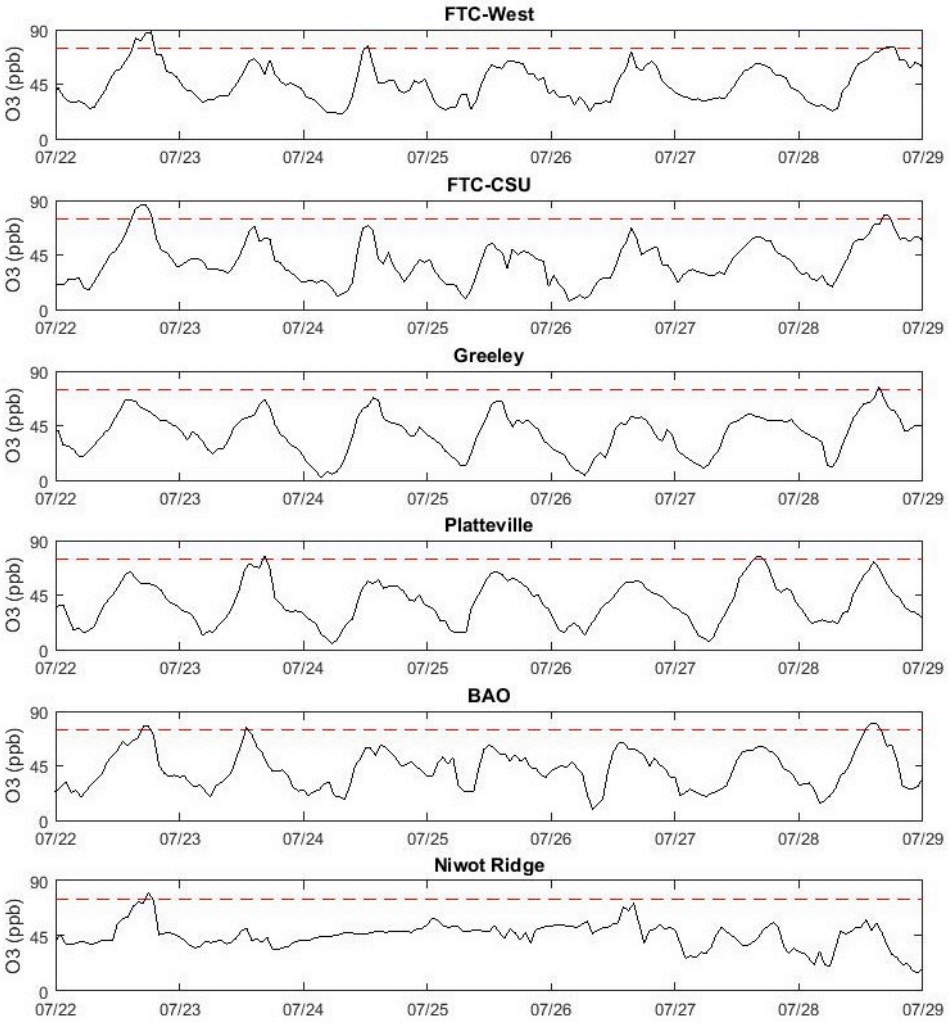


Days w/ peak O_3 >75 ppb
(Jun-Aug 2013-2015)

~15% of days in Front Range, 10% of days at Niwot Ridge

Summer 2014 and Spatial Variability

- July 16 – August 16, 2014: FRAPPE and DISCOVER-AQ field campaigns
- Cool and damp during July and August, 2014
- 2014 was low O_3 summer overall
- Some days O_3 high at multiple sites, other days more localized
  - Influence of local and regional precursor sources
  - High O_3 observed throughout Front Range and not confined to Denver area



Case Studies

- Dates: July 23, August 3, August 13, 2014
- Weather summary
  - July 23: max temp 32°C, clear sky after AM
  - August 3: max temp 31°C, clear sky
  - August 13: max temp 33°C, clear sky
- Types of data included
  - Mobile laboratory gas measurements (Aerodyne)
  - Mobile laboratory wind data (Aerodyne)
  - Discrete air samples in flasks (UC Irvine)
  - Surface monitoring sites (CDPHE, NOAA, and NASA)

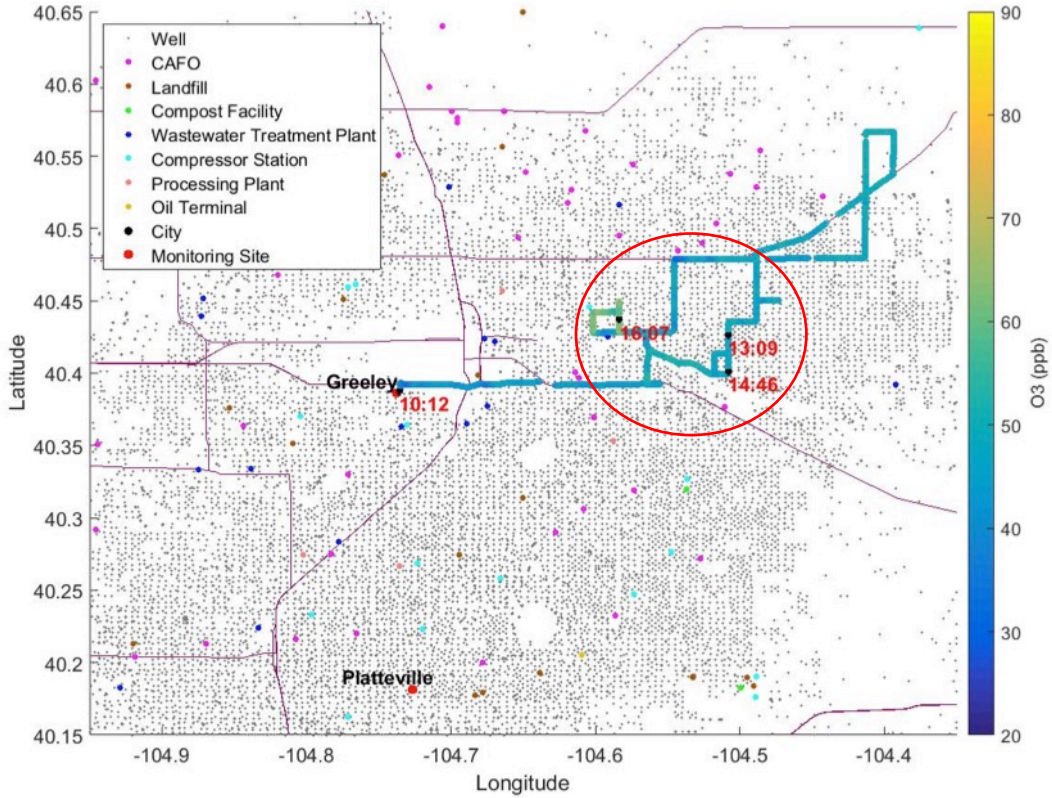
July 23: O&G emissions, moderate O_3 levels

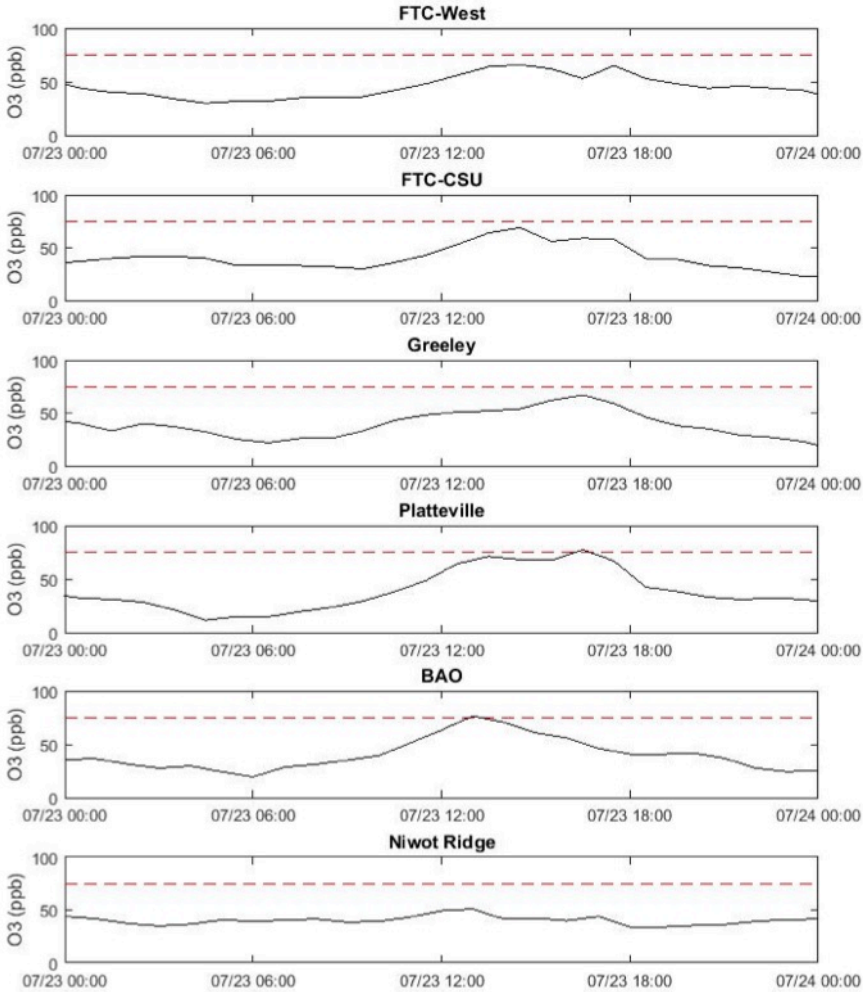
Drive start: 10:00 (LST)

Drive end: 16:10

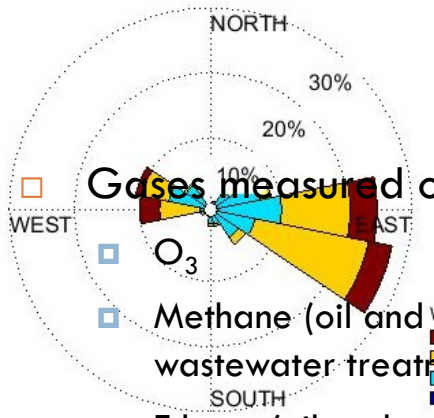
Surface O_3 at monitoring sites:

- BAO: >75 ppb
- Platteville: >75 ppb
- Greeley, Fort Collins, Niwot Ridge all moderate



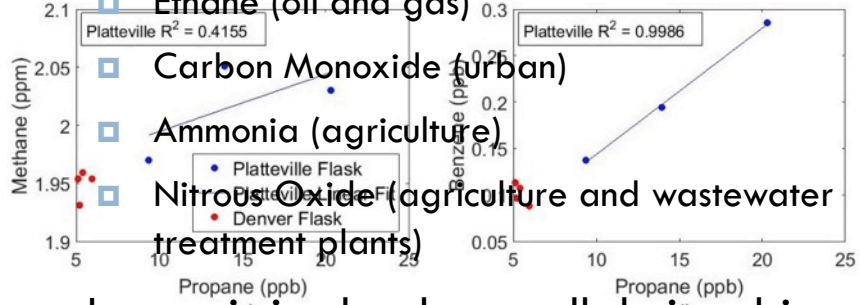


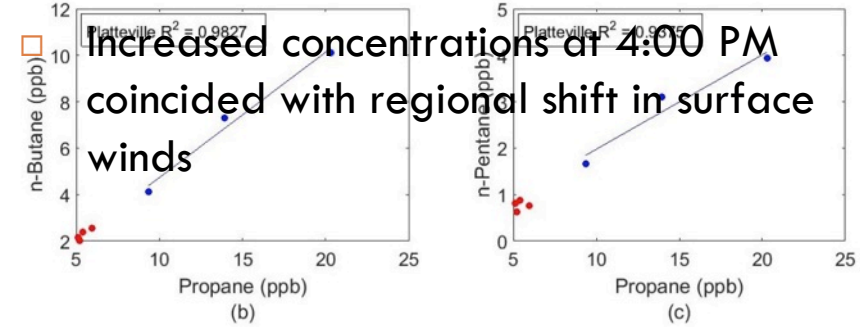
July 23: O&G emissions, moderate O_3 levels

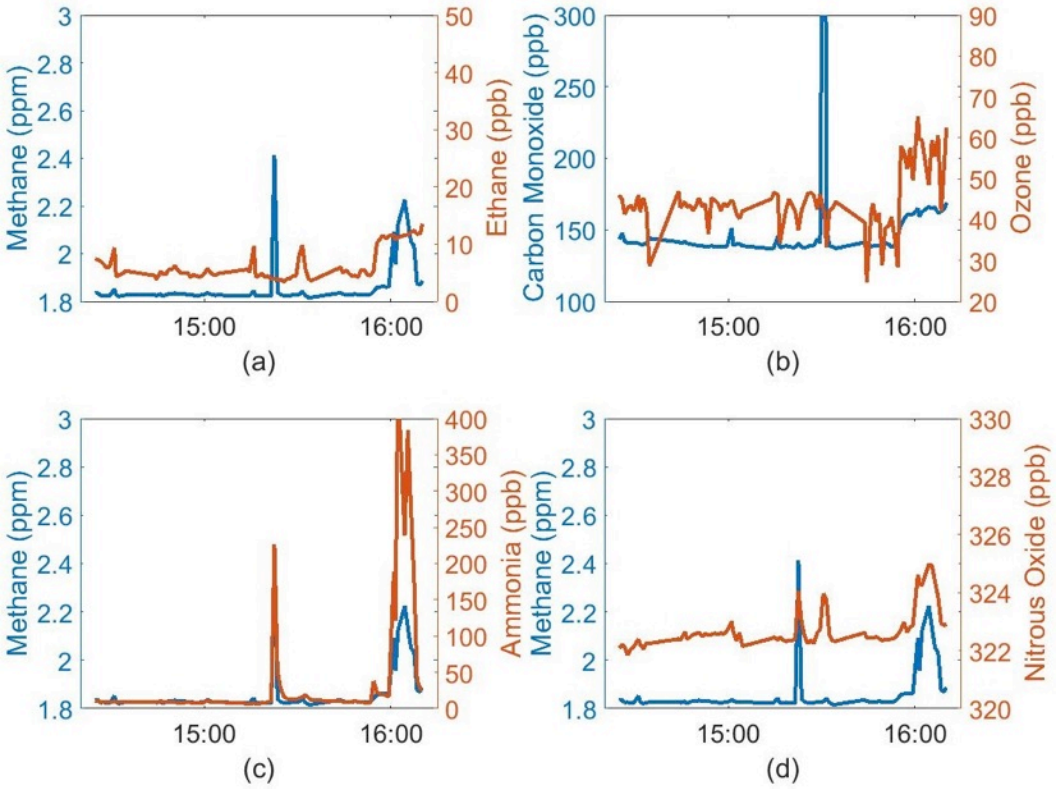


Wind rose from mobile lab during 14:00-16:10

- Gases measured on mobile labs:
  - O_3
  - Methane (oil and gas, agriculture, landfills, wastewater treatment plants)
  - Ethane (oil and gas)
  - Carbon Monoxide (urban)
  - Ammonia (agriculture)
  - Nitrous Oxide (agriculture and wastewater treatment plants)
- Low emission levels overall during drive
- Increased concentrations at 4:00 PM coincided with regional shift in surface winds







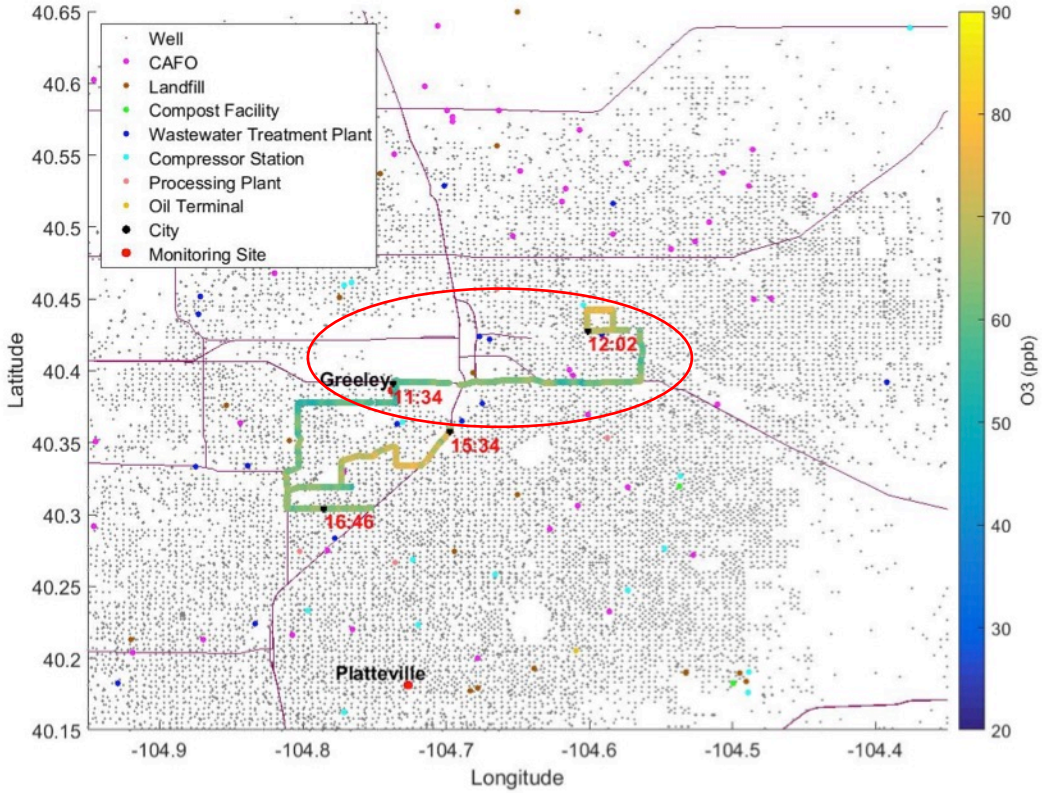
August 3: Mixed emissions, high O_3 day

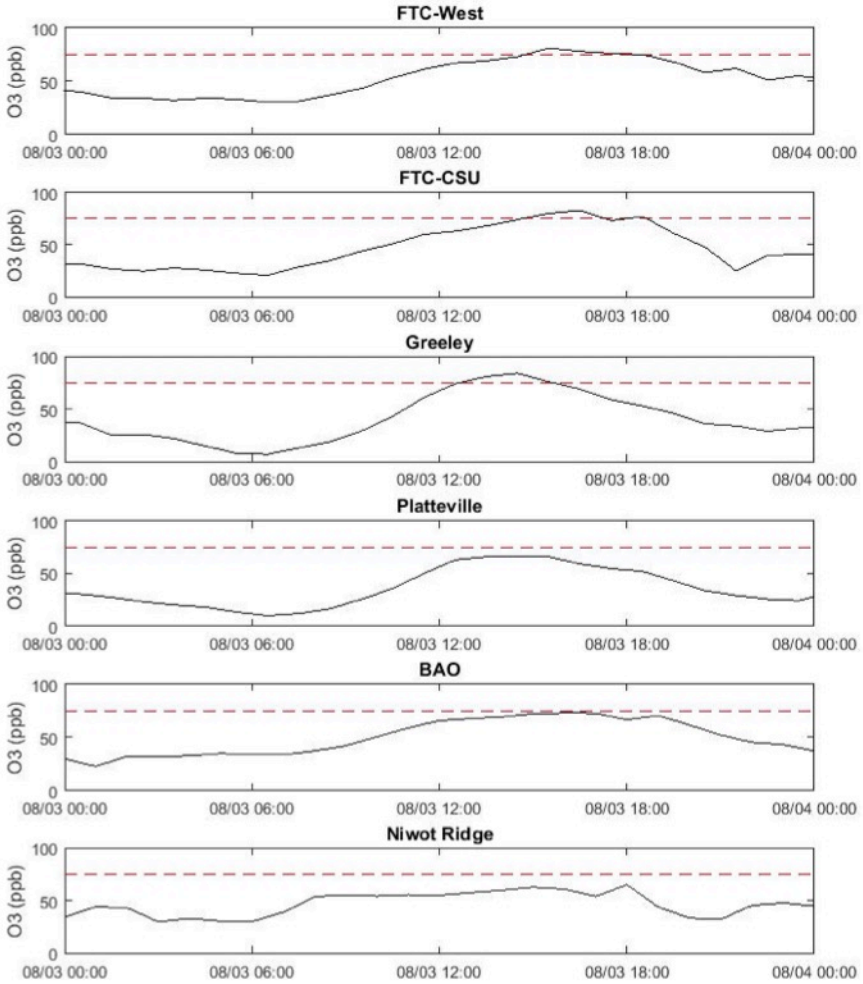
Drive start: 10:15

Drive end: 18:00 (interrupted at 12:45)

High O_3 at monitoring sites:

- Greeley: >80 ppb
- FTC (both sites): >80 ppb





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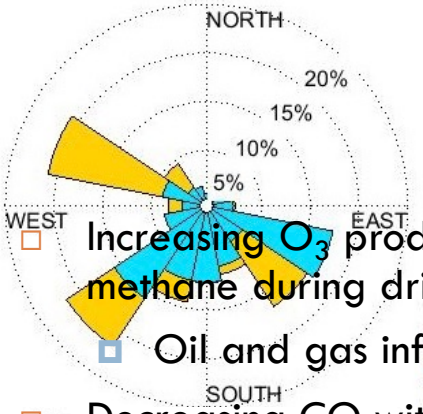
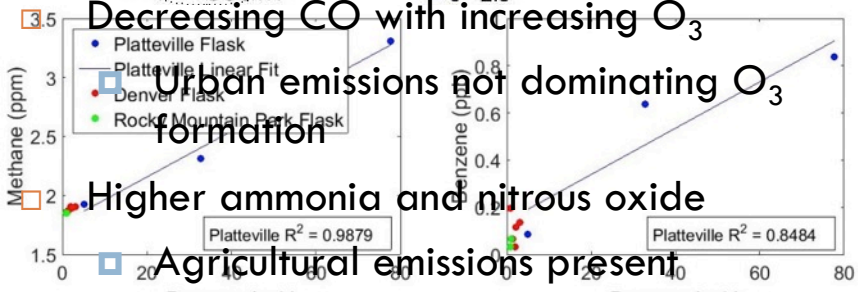
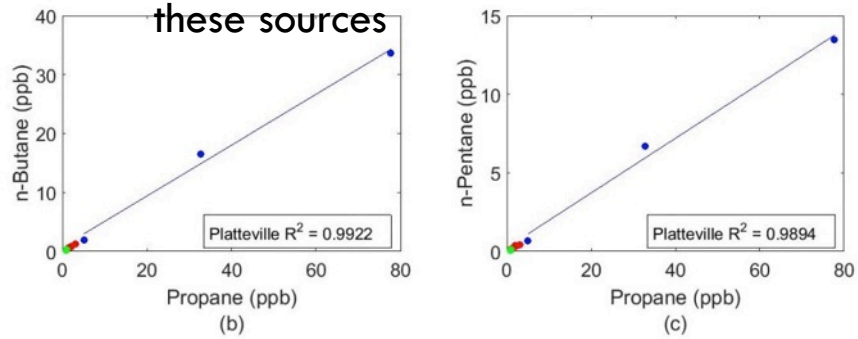
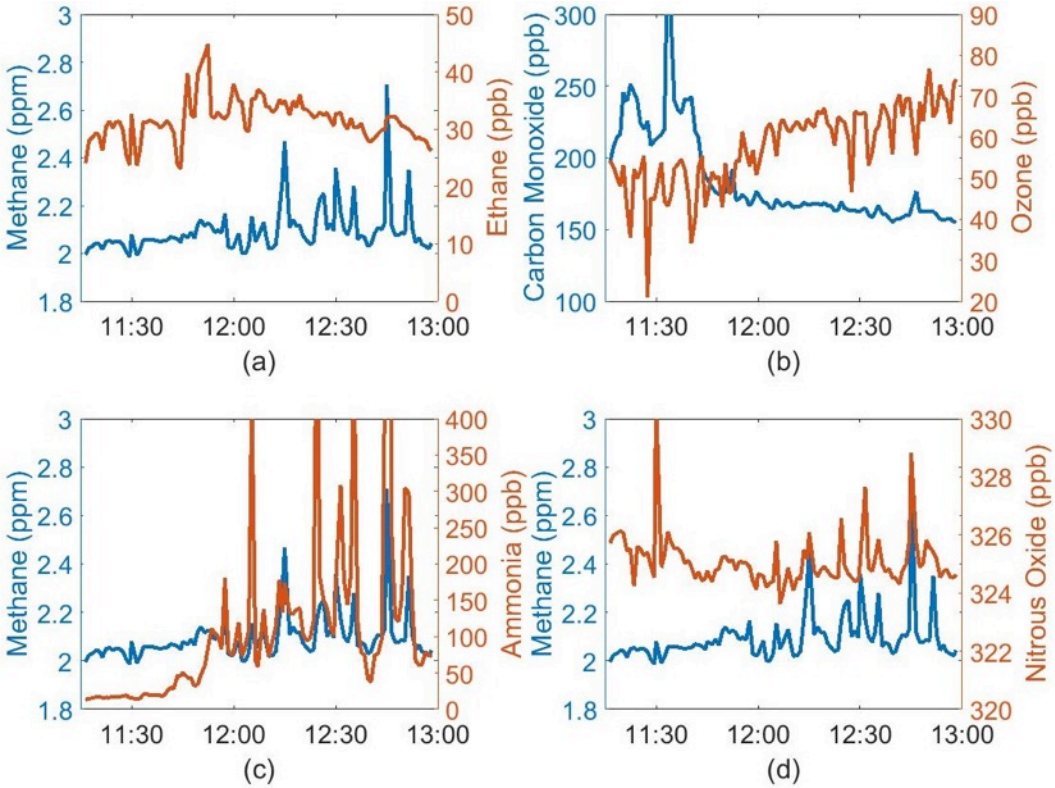


Wind rose from mobile lab during 11:15-13:00

- Increasing O_3 production, ethane, and methane during drive
  - Oil and gas influence
- Decreasing CO with increasing O_3
  - Urban emissions not dominating O_3 formation
- Higher ammonia and nitrous oxide
  - Agricultural emissions present
  - Less potential for O_3 production from these sources







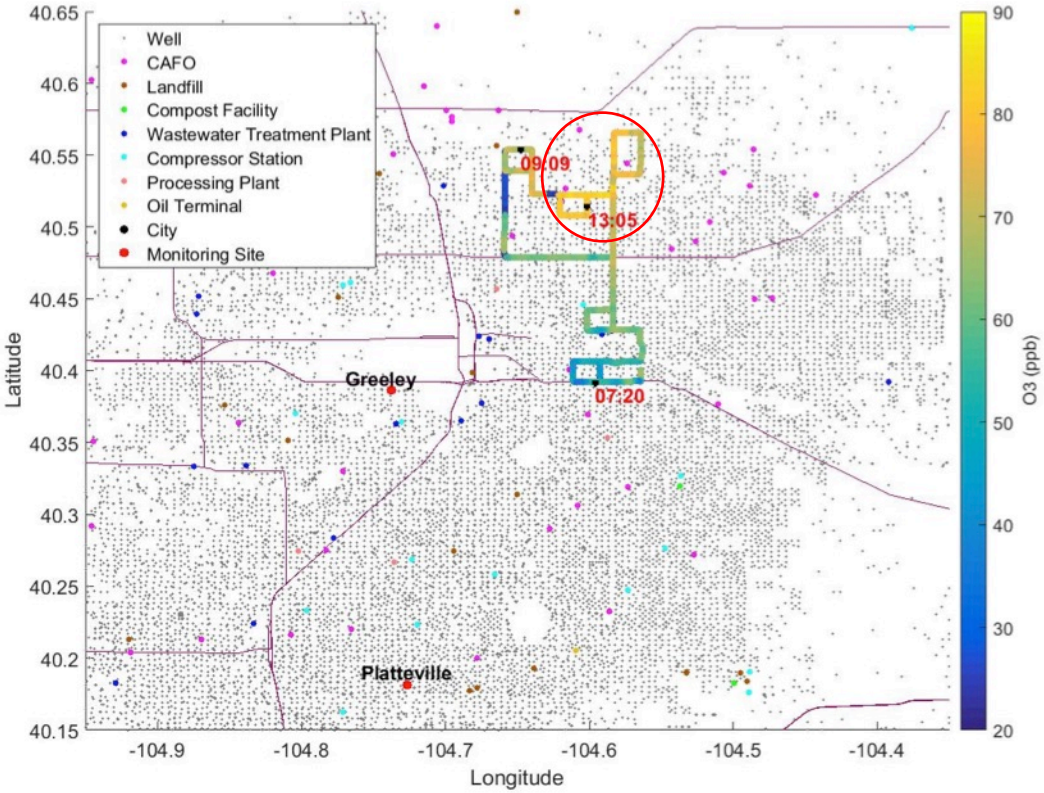
August 13: O&G emissions and localized elevated O_3

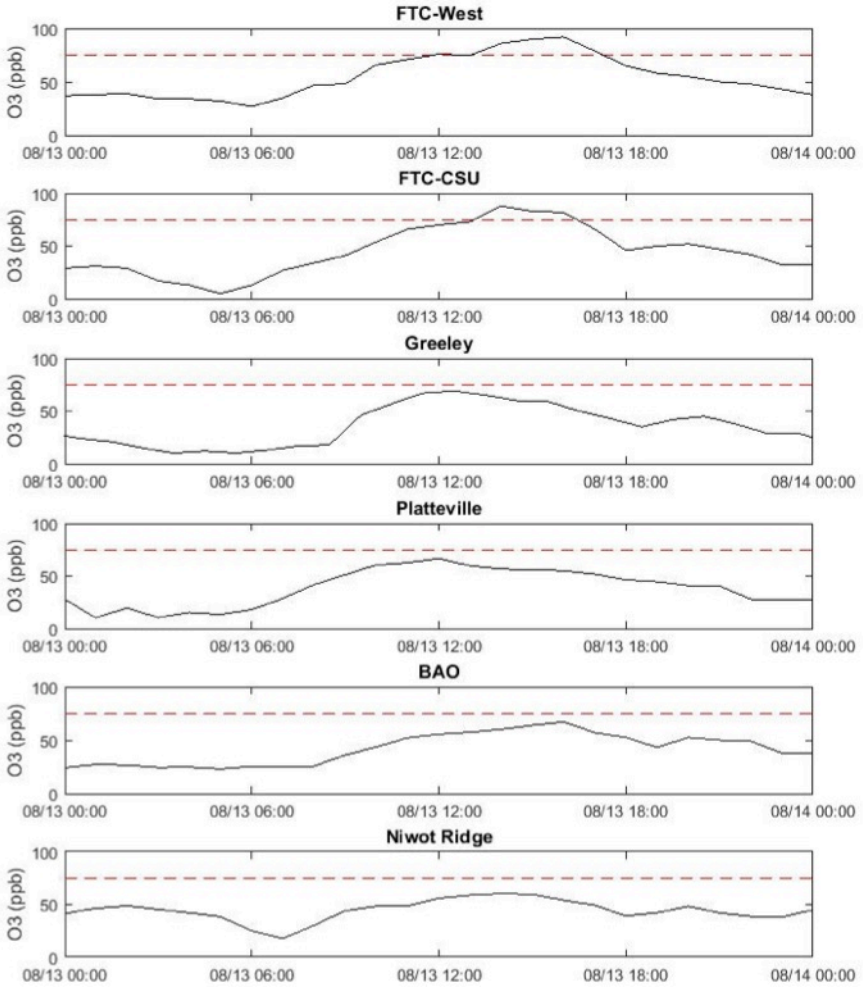
Drive start: 7:20

Drive end: 14:20

High O_3 at monitoring sites:

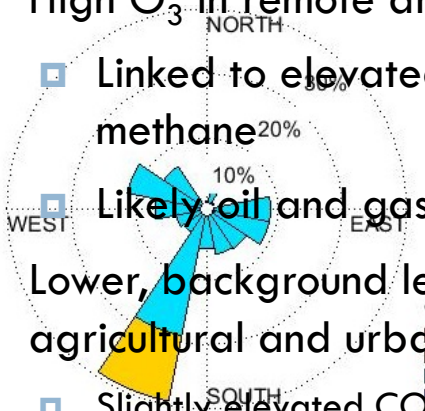
- FTC-CSU: peak of ~90 ppb
- Greeley and Platteville: peak of ~70 ppb



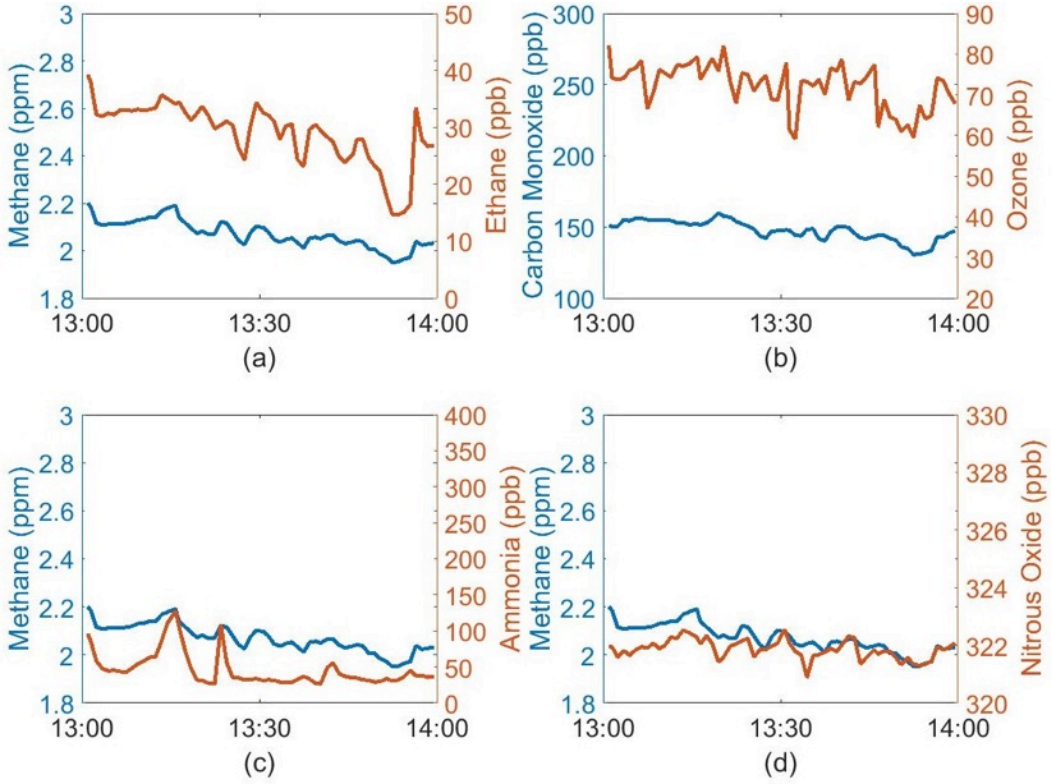


August 13: O&G emissions and localized elevated O_3

- High O_3 in remote area
  - Linked to elevated ethane and methane
  - Likely oil and gas precursor source
- Lower, background levels of agricultural and urban emissions
  - Slightly elevated CO correlated with ethane but not acetylene
- O_3 levels at ~30 ppb above background

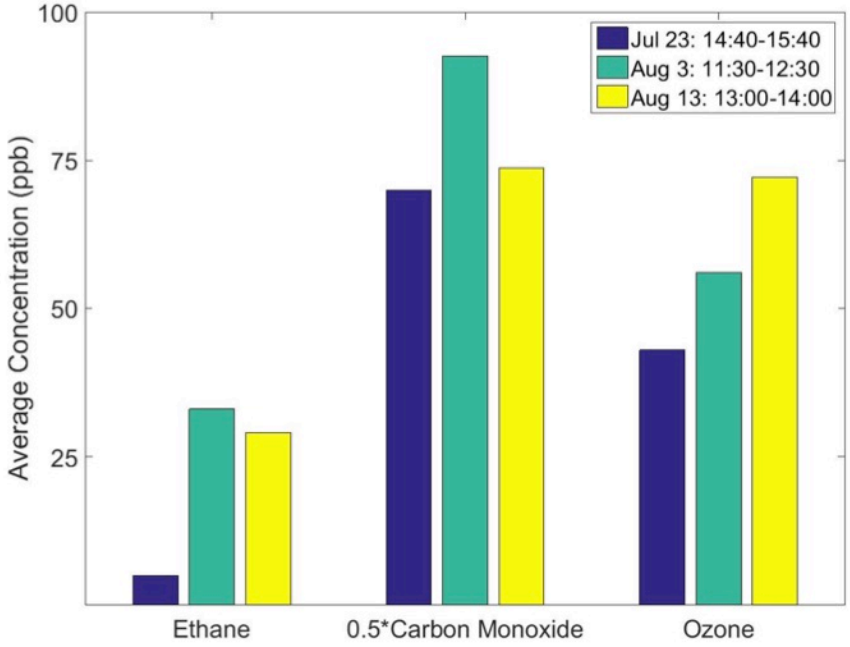


Wind rose from mobile lab during 13:00-14:00



Conclusions

- "Background" O_3 in Front Range ~40-45 ppb
- Mobile lab drives measuring O_3 at 30-35 ppb above "background"
- Influence from four main sectors on local emissions as seen in methane levels
  - Oil and gas, urban, agriculture, wastewater treatment plants
- Large influence of oil and gas emissions on O_3 formation
  - Some influence of urban emissions on O_3
  - All case studies show potential influence of oil and gas
  - Aug 13 shows most unambiguous evidence of oil and gas as source of O_3 precursors with enhancement up to 30 ppb of O_3



Additional Slides

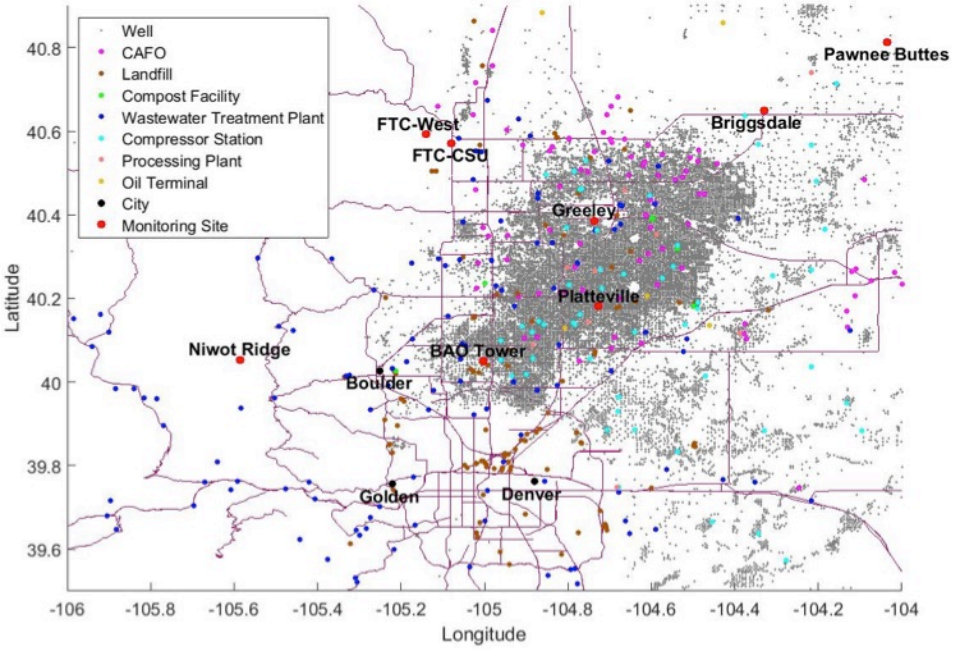
Surface Sites NE of Greeley

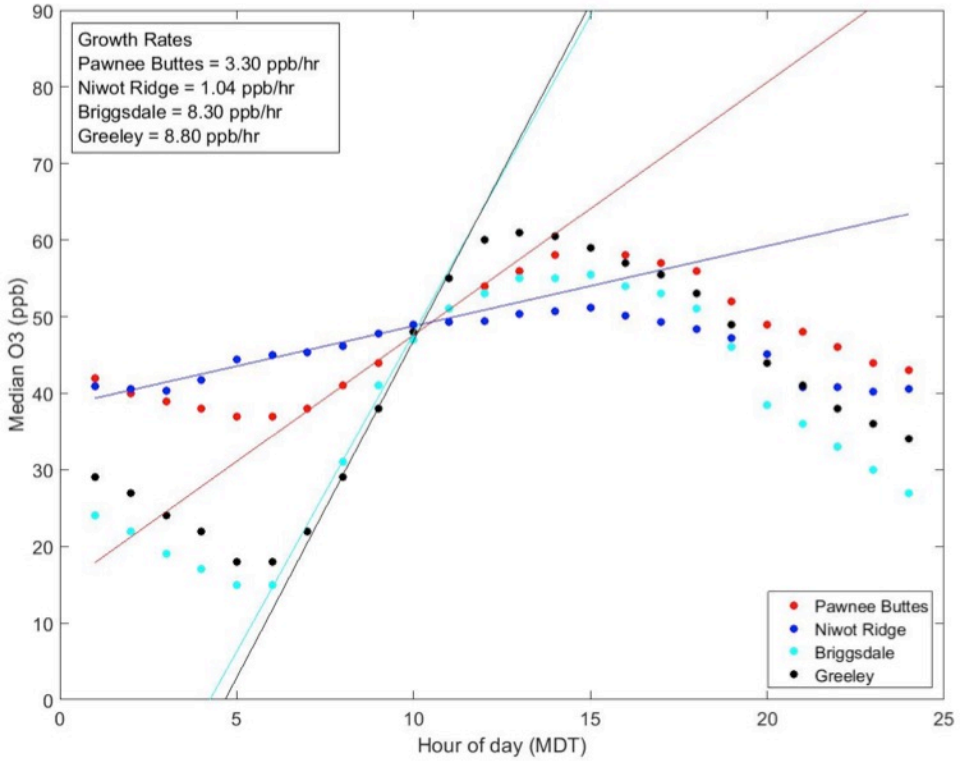
Isoprene in Flasks

MesoWest Winds August 13

References

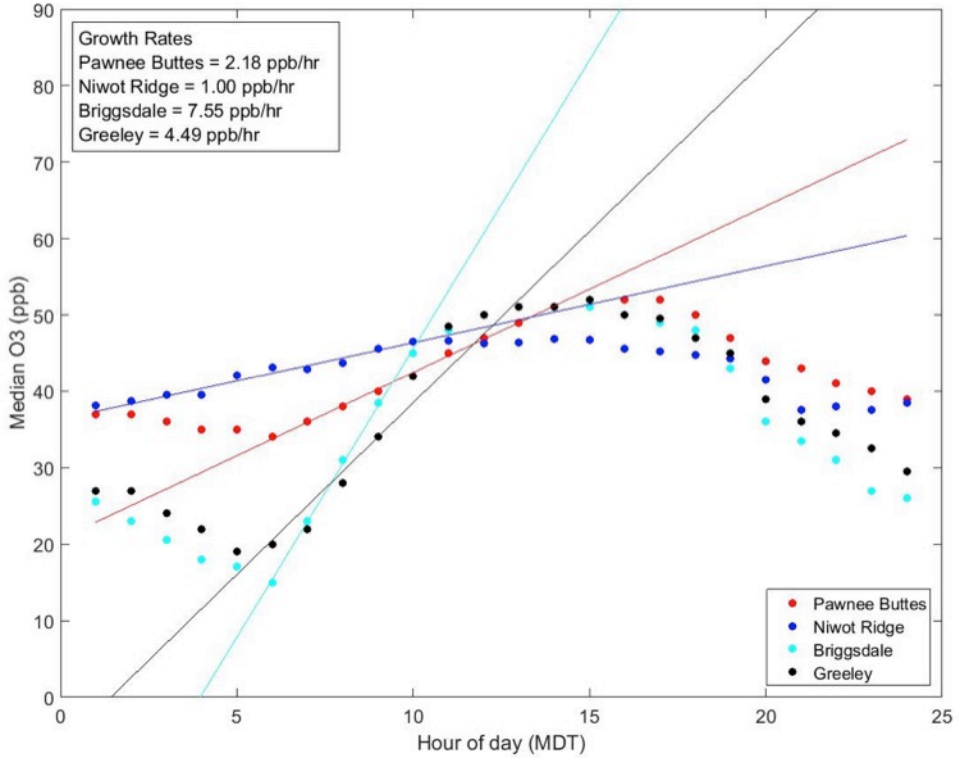
Additional NE Sites



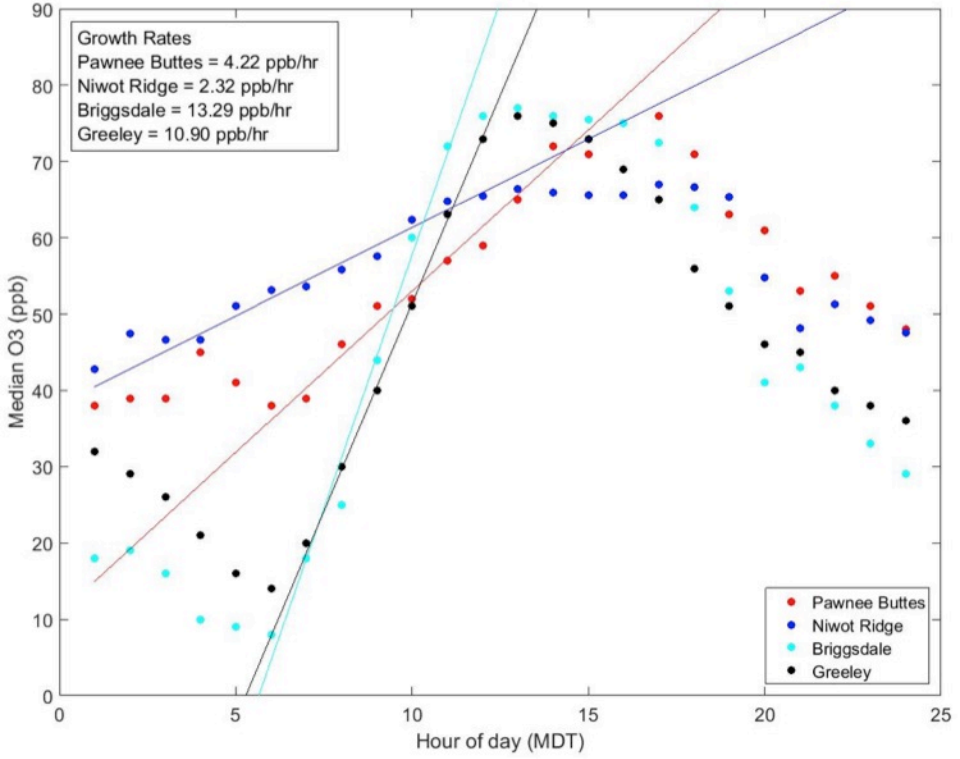


All days June, July, August 2013-2015

Additional NE Sites

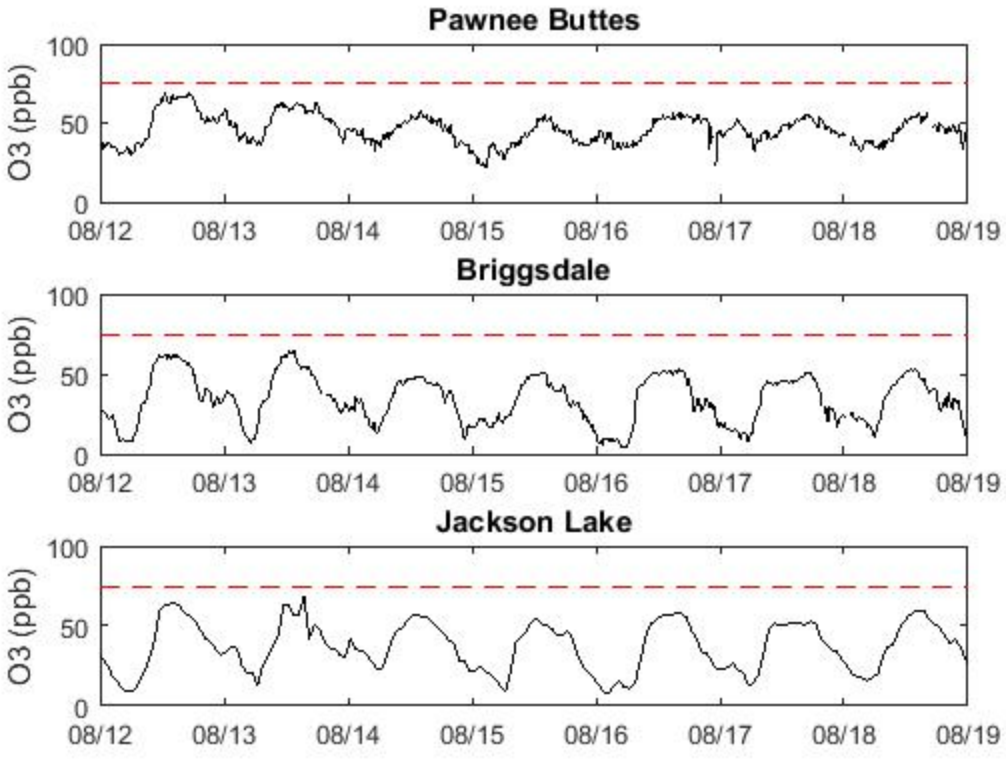


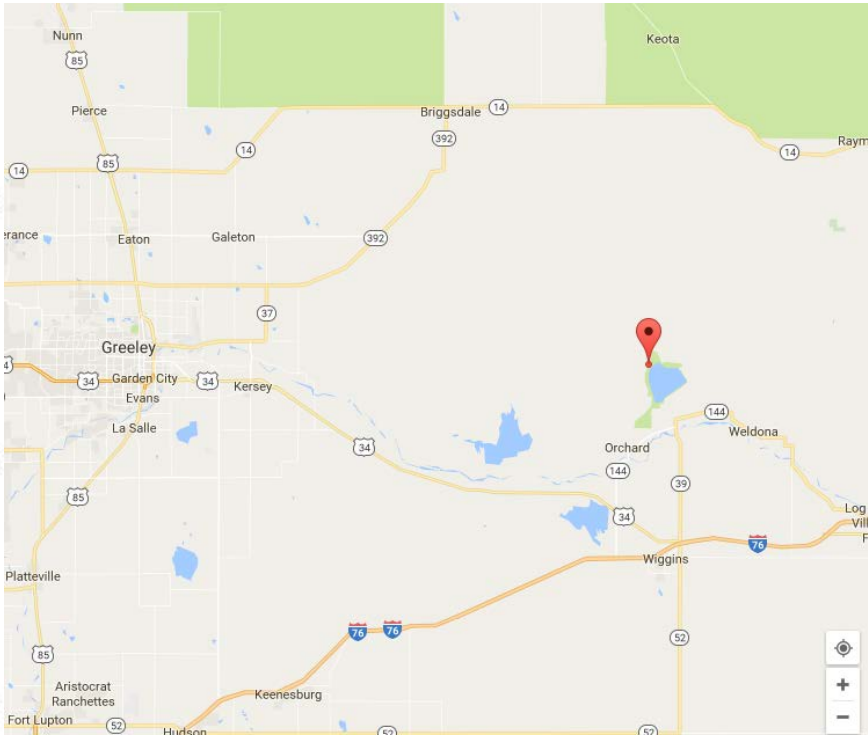
Days w/ peak O_3 <60 ppb



Days w/ peak O_3 >75 ppb

Additional NE Sites – 1 Week



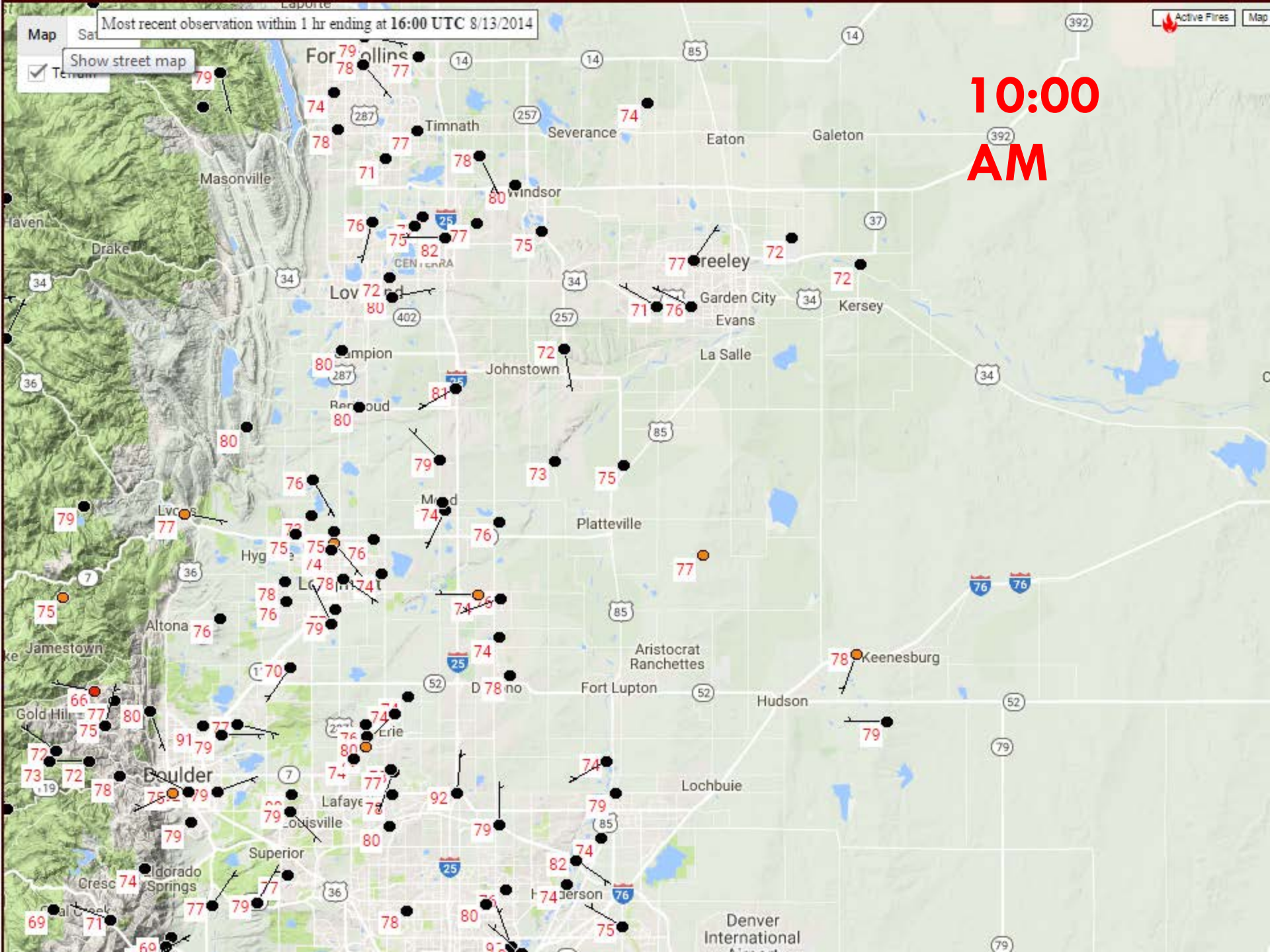


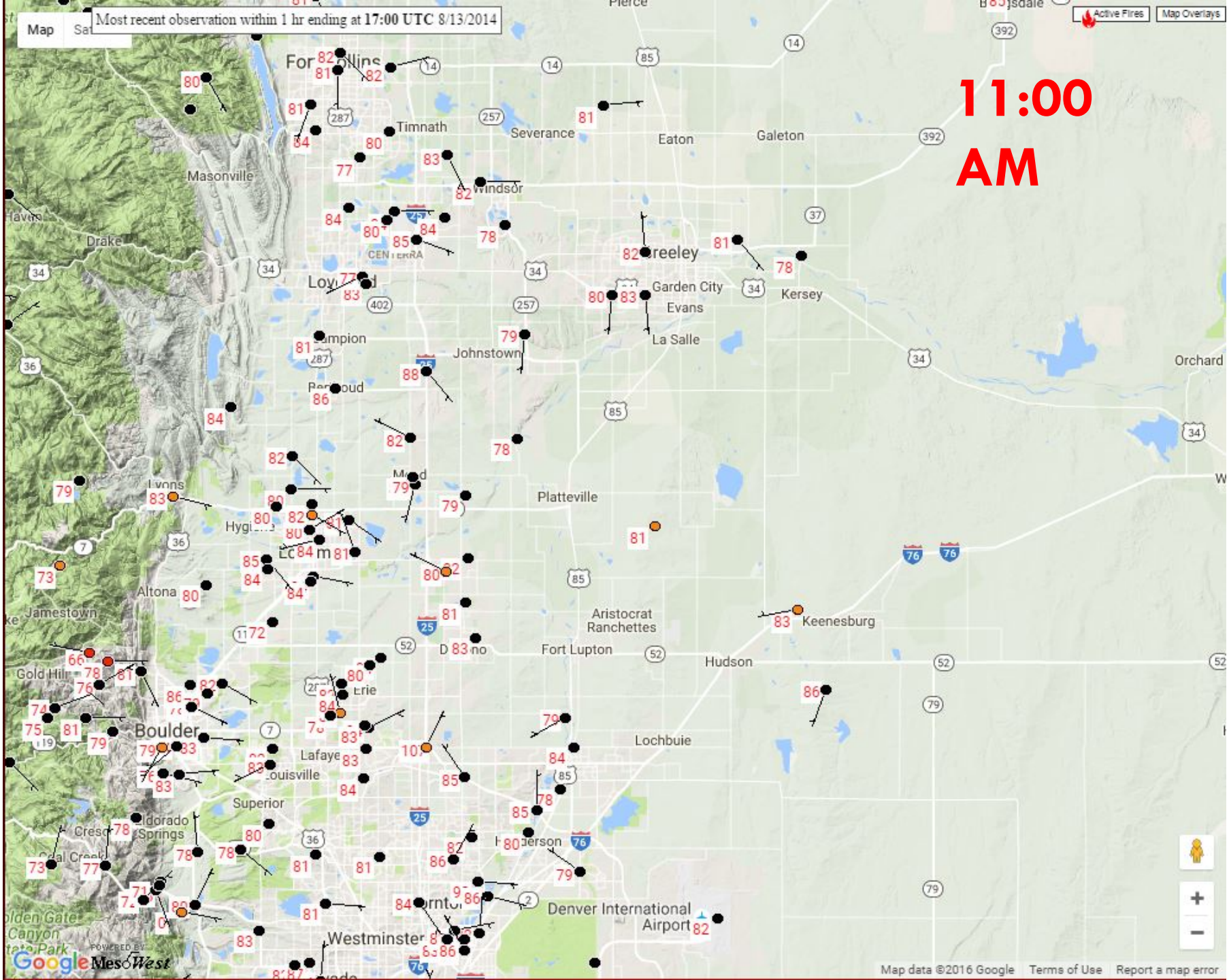
Isoprene in Platteville

- Isoprene is the most prevalent naturally occurring biogenic VOC in the northern Front Range and the average mixing ratio measured at the BAO Tower during the summer of 2015 was 0.2 ppb (Abeleira et al., 2017)
- Measurements of isoprene in Platteville
  - July 23 average: 0.04 ppb
  - August 3 average: 0.03 ppb
  - August 13 average: 0.06 ppb
- All case study values less than the 0.2 ppb average measured at BAO Tower during summer 2014. Biogenic VOCs likely did not contribute as much to O_3 production during case studies than during summer 2015

August 13, 2014
MesoWest Surface Winds

10:00 AM, 11:00 AM, 12:00 PM, 1:00 PM


Map
Show street map
Most recent observation within 1 hr ending at 16:00 UTC 8/13/2014
Active Fires
Map
10:00
AM
Timnath
Severance
Eaton
Galeton
Masonville
Windsor
Drake
Garden City
Evans
Kersey
La Salle
Johnstown
Platteville
Altona
Jamestown
Aristocrat
Ranchettes
Keenesburg
Fort Lupton
Hudson
Gold Hill
Boulder
Lochbuie
Superior
Denver
International


Map
Most recent observation within 1 hr ending at 17:00 UTC 8/13/2014
Active Fires
Map Overlays
11:00 AM
Fort Collins
Timnath
Severance
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Galeton
Windsor
Greeley
Garden City
Evans
La Salle
Kersey
Johnstown
Platteville
Orchard
Aristocrat Ranchettes
Keenesburg
Fort Lupton
Hudson
Lochbuie
Boulder
Lafayette
Louisville
Superior
Denver International Airport
Westminster
Jamestown
Altona
Masonville
Drake
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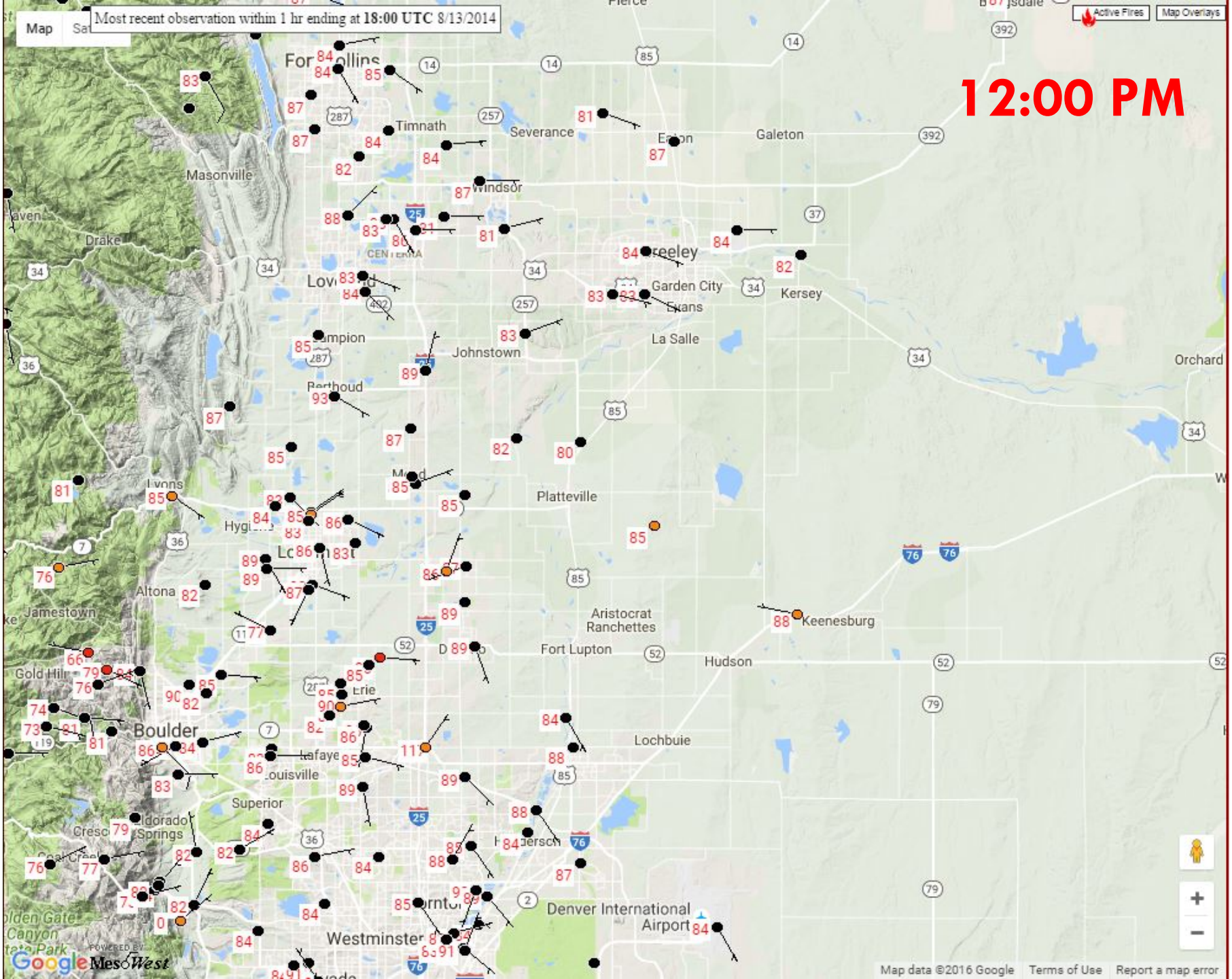
Most recent observation within 1 hr ending at 18:00 UTC 8/13/2014
12:00 PM
Fort Collins
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Garden City
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La Salle
Johnstown
Platteville
Orchard
Lyons
Hygiene
Longmont
Altona
Jamestown
Aristocrat Ranchettes
Keenesburg
Fort Lupton
Hudson
Erie
Boulder
Lafayette
Louisville
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Superior
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Westminster
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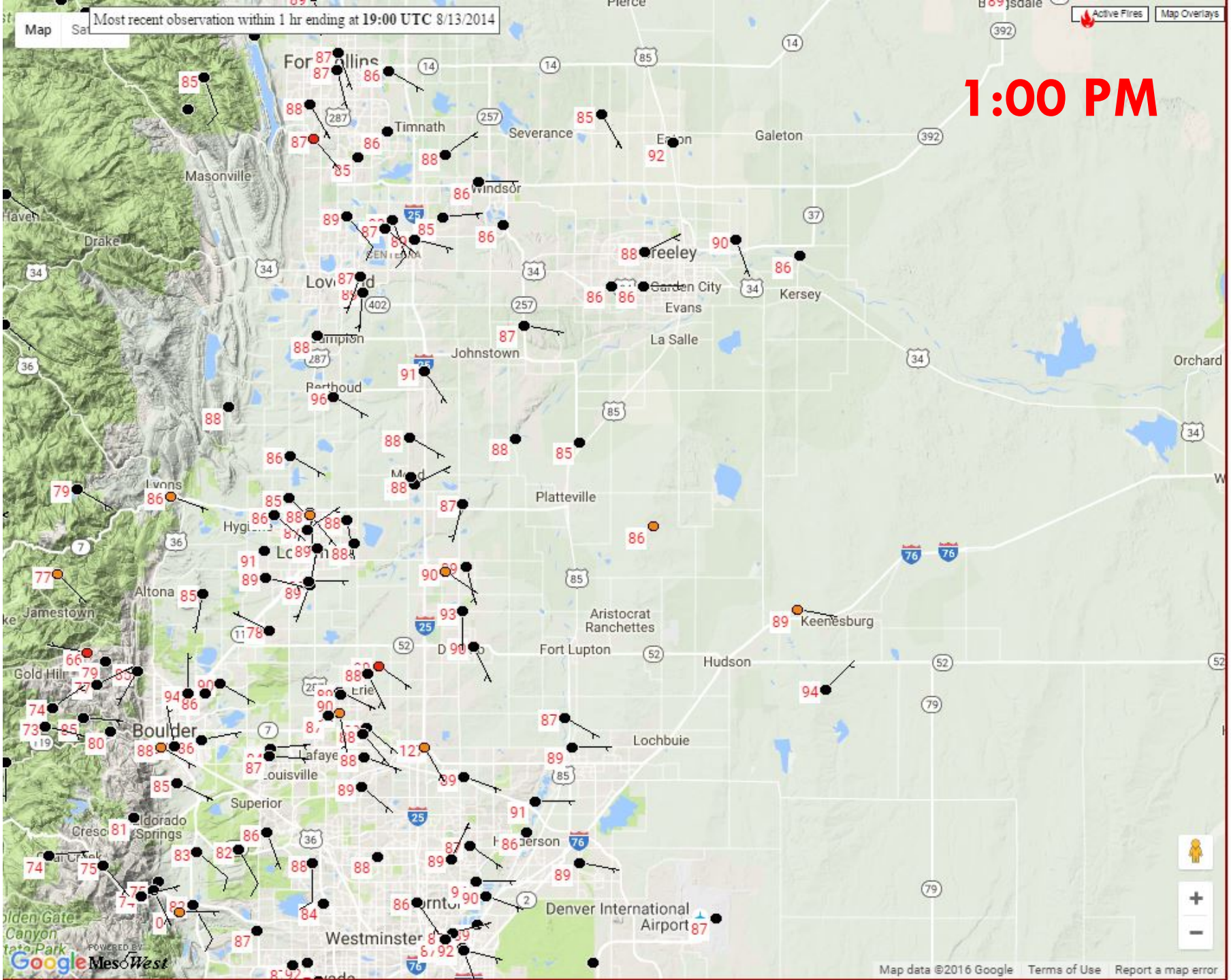
Map
Most recent observation within 1 hr ending at 19:00 UTC 8/13/2014
Active Fires
Map Overlays
1:00 PM
Fort Collins
Timnath
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Masonville
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Drake
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Garden City
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Keenesburg
Lochbuie
Commerce City
Denver International Airport
Westminster
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