What is Known about Ozone

• Ozone is formed through complex, non-linear reactions between Nitrogen Oxides (NOx) and Volatile Organic Compounds (VOCs) in the presence of sunlight

• Ozone precursors can react and form ozone locally, and they can also travel and react far from where they were emitted making ozone a local, regional and increasingly a global issue

• VOCs emitted from Oil and Gas (O&G) Operations can lead to the formation of ozone
NOAA’s HYSPLIT Model creates “Back-Trajectories” showing the path and speed of air flow

NOAA HYSPLIT MODEL
Backward trajectory ending at 01 UTC 19 Jul 03
EDAS Meteorological Data

Source: Air Pollution Control Division, State of Colorado.
Use HYSPLIT wind speed and direction data to show likelihood that air traveled through a certain point before reaching Rocky Mountain National Park in 2009.

Source: Gebhart et al., 2014. Submitted.
Spring 2006 Residence Time Map

Summer 2006 Residence Time Map

Current Colorado O&G Well Locations (Red dots) and Shale Basins (Green Areas)

Source: COGCC GIS O&G Well Locations Updated Daily. Available at: http://cogcc.state.co.us/Home/gismain.cfm
Basin Boundaries from EIA: http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/maps/maps.htm#shaleplay
Summer 2006 Residence Time Map

Two Examples of Ozone (> 75 ppb) in Rural areas occurring as a direct result of O&G activity

- Uinta Basin, Utah

What Scientists know:
- Requires Snow Cover
- Very Stagnant Air and Shallow Boundary Layer
- Emissions of ozone precursors from O&G activities
- These are NOT unique characteristics!

Scientists suggest that winter-time ozone could be occurring in other non-monitored regions of the US as a result of O&G activities\(^1\).

Colorado O&G Well Map with AQ Monitor Locations (Yellow Boxes)
Modeled Impacts of O&G VOC emissions in the Non-Attainment Area

• Results include thirteen days in a June/July 2006 modeling episode with modeled ozone concentration greater than 70 ppb at Greeley monitor (Weld Tower)

• Greeley monitor model result statistics:
  – Average ozone concentration 72 ppb (of 13 “high” days)
  – Average contribution from in-state sources 17 ppb
  – Average contribution from O&G VOC emissions 1 ppb (5% of controllable emissions on average)
  – Contribution from O&G VOC emissions > 2 ppb on four days
  – On three days, ozone would be below 70 ppb if O&G VOC emissions were eliminated

Source: Modelling conducted by ENVIION on behalf of the DGS group and submitted as Exhibit RR in the DGS Prehearing Statements.
2008 Modeling results show widespread ozone decreases (right column) as a result of a 20% reduction in VOC emissions from O&G in the Denver/Julesburg Basin.
Two Methods To Estimate Emissions: “Bottom Up” and “Top Down”

• In Colorado, these two sources of emissions estimates do not match and scientists are working hard to understand why.

• Top down estimates suggest that bottom up inventories under-estimate VOC emissions from O&G by 50 – 200%\(^1,2\).