

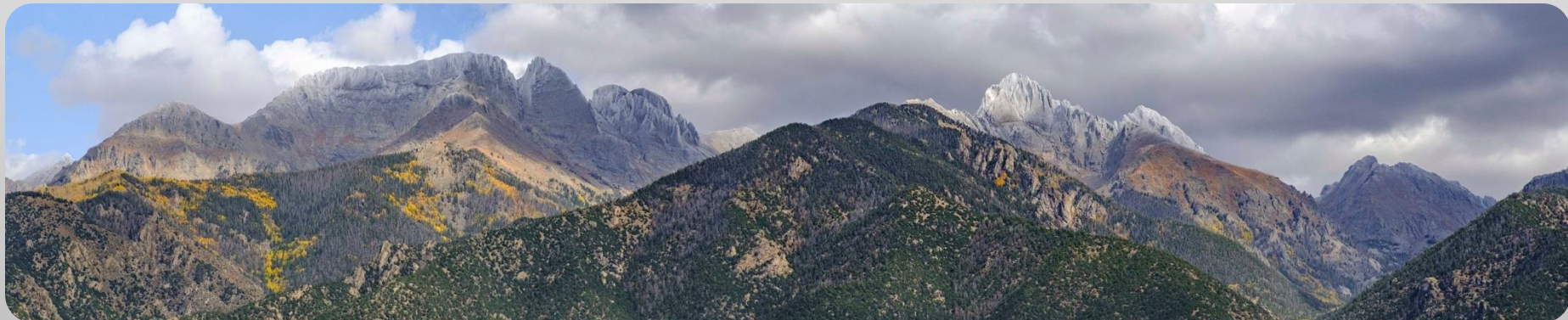
Synthesis of Satellite and Surface Measurements, Model Results, and FRAPPÉ Study Findings to Assess the Impacts of Oil and Gas Emissions Reductions on Maximum Ozone in the Denver Metro and Northern Front Range Region In Colorado

<https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2023EA002917>

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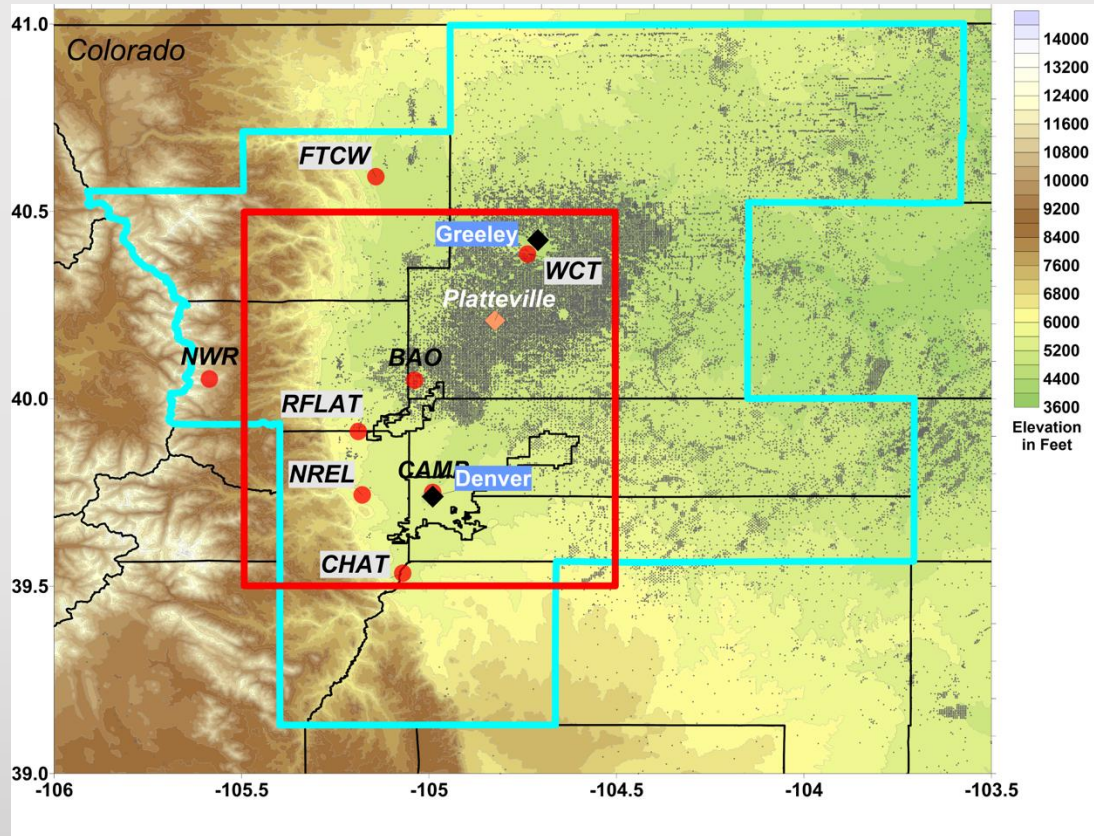
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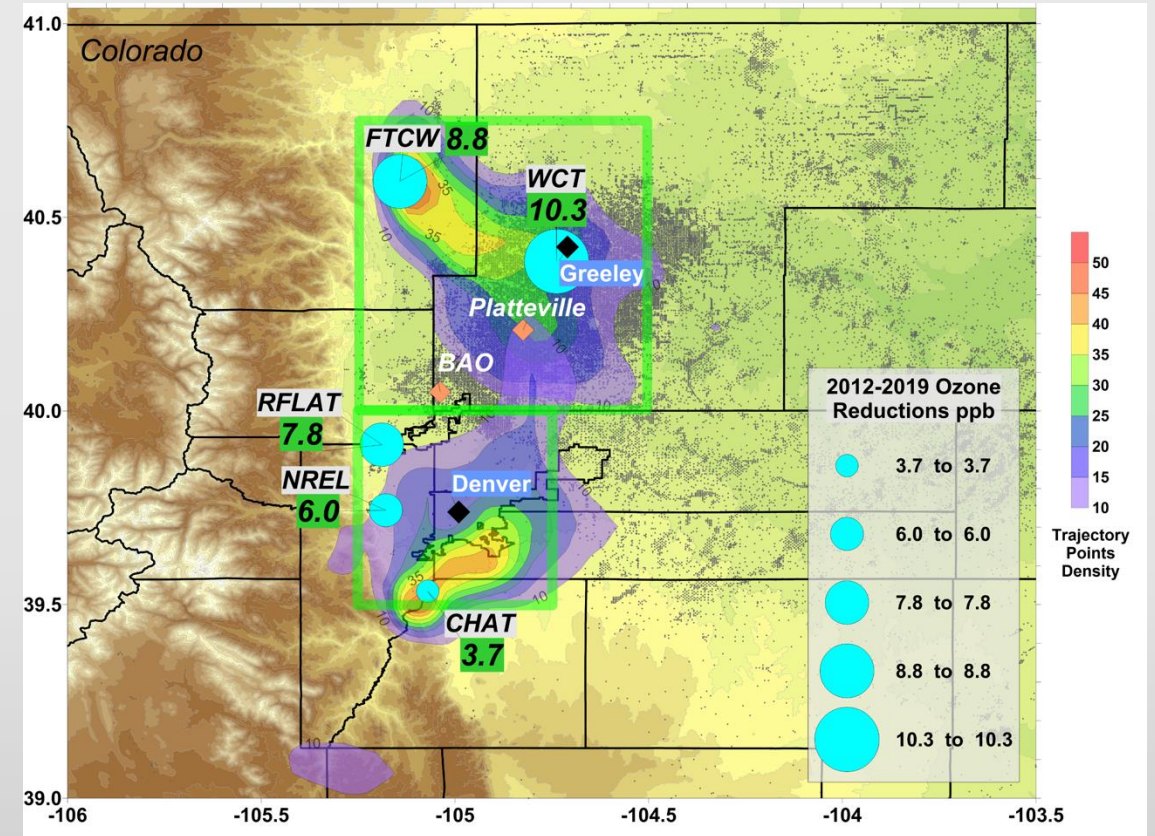
- **Colorado has a robust program of O&G emissions control regs that ramped up after 2014.**
- **Oil production increased by 343% and gas production by 297% from 2012 to 2020.**
- **How have O&G air quality impacts changed?**



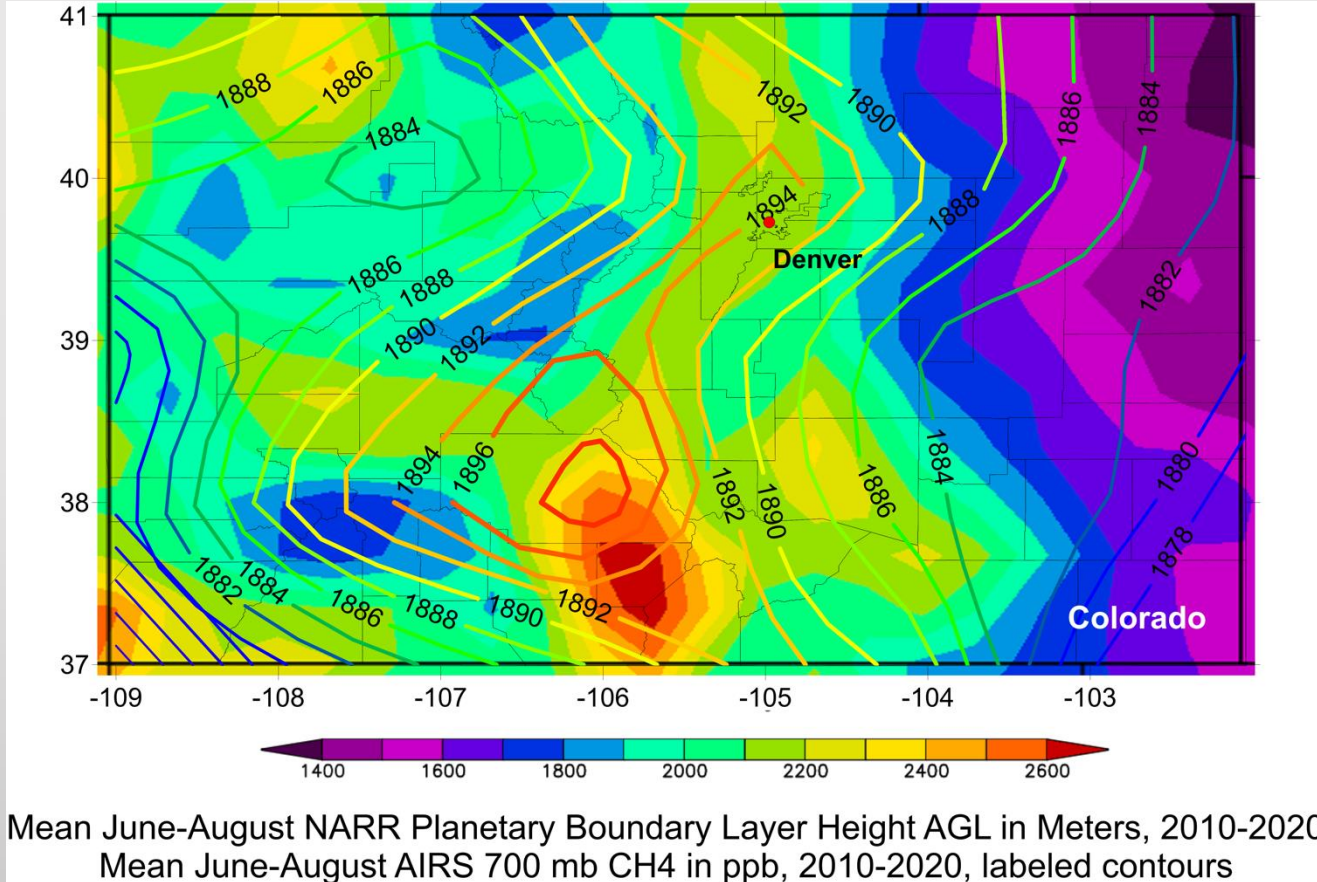
FRAPPE papers and a source apportionment study show that O_3 from O&G peaks in the north.



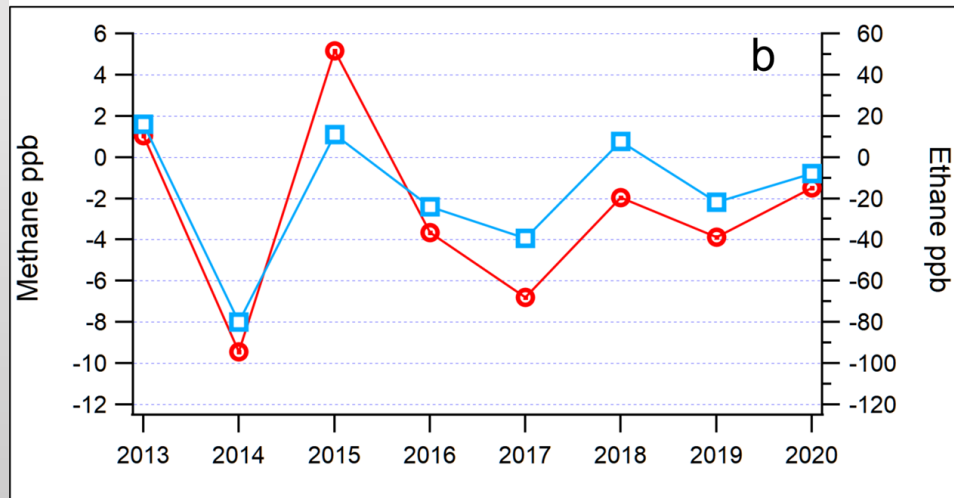
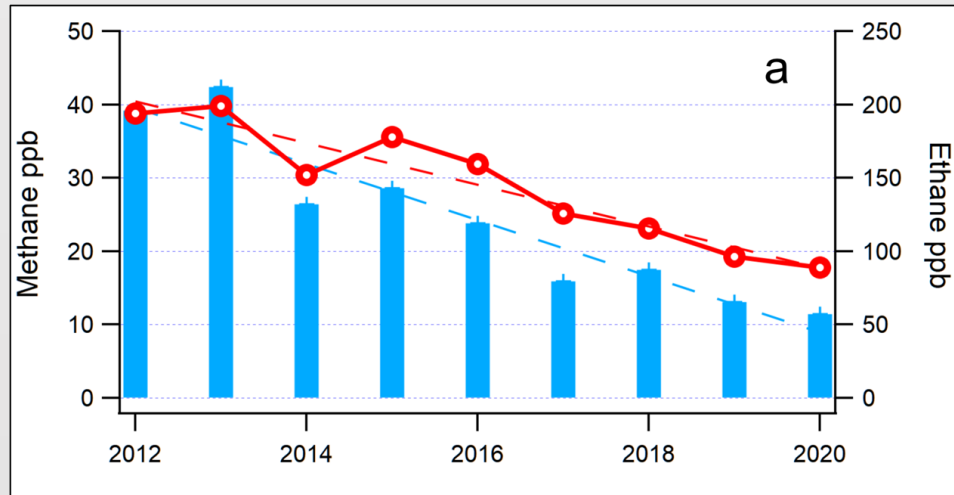
- Denver Metro/Northern Front Range (DM/NFR) O_3 Nonattainment Area in blue
- **AIRS v7 700 mb methane** grid cell in red
- Oil and gas wells in grey
- 5 high-concentration O_3 sites
- NOAA GML Niwot Ridge (NWR) background methane site.



- HYSPLIT footprints for high concentration events
- **OMI NO_2** grids for O&G area (top square) and urban area (bottom square)
- Oil and gas wells in grey
- Reductions in annual 4th max O_3 2012-2019 at high-concentration sites (*after filtering out natural events*)

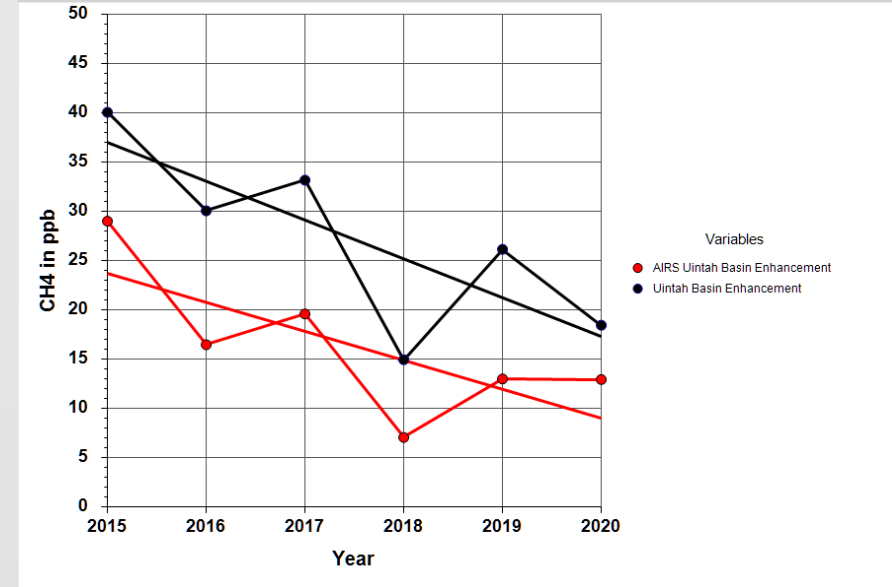


- AIRS is most sensitive to CH₄ in the upper troposphere and stratosphere and for altitudes > 2 km.
- Regions of Colorado with deeper planetary boundary layer heights in the summer tend to have higher AIRS 700 mb CH₄ and vice versa.
- The AIRS 700 mb product can detect CH₄ from surface sources in summer in Colorado because of deep vertical mixing.
- AIRS 700 mb CH₄ was within 15 ppb of NASA P3 PBL measurements in July/Aug of 2014
- Niwot Ridge (NWR) methane was subtracted from the AIRS 700 mb CH₄ to derive DM/NFR enhancements.
- The Colorado Department of Public Health and Environment Platteville site is representative for O&G emissions.
- Platteville ethane is used as a tracer for O&G emissions of VOCs.

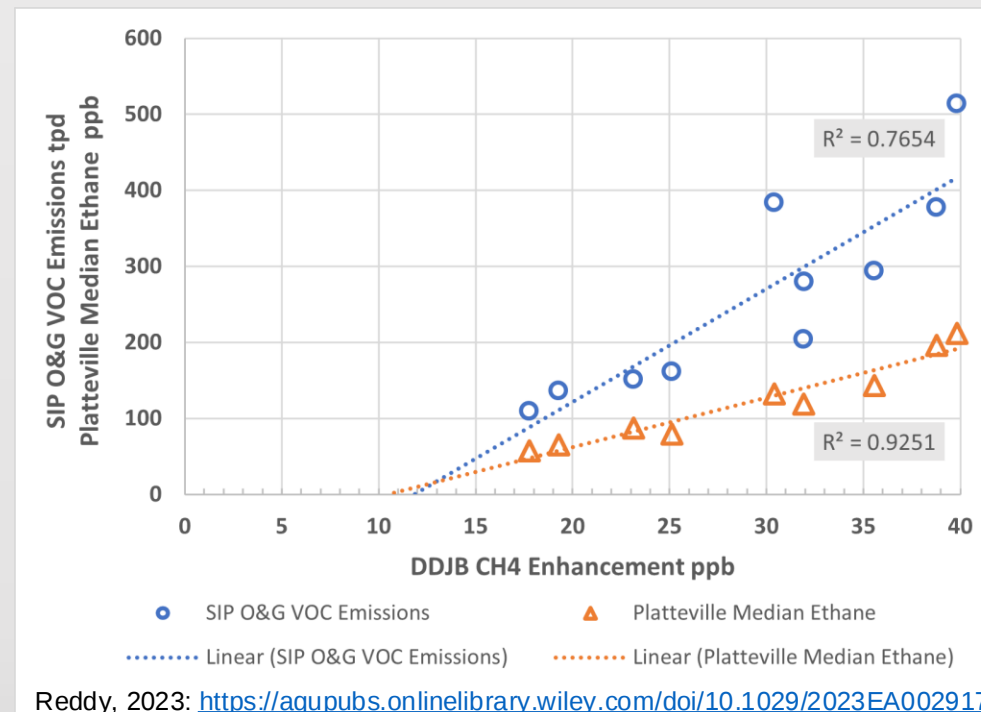
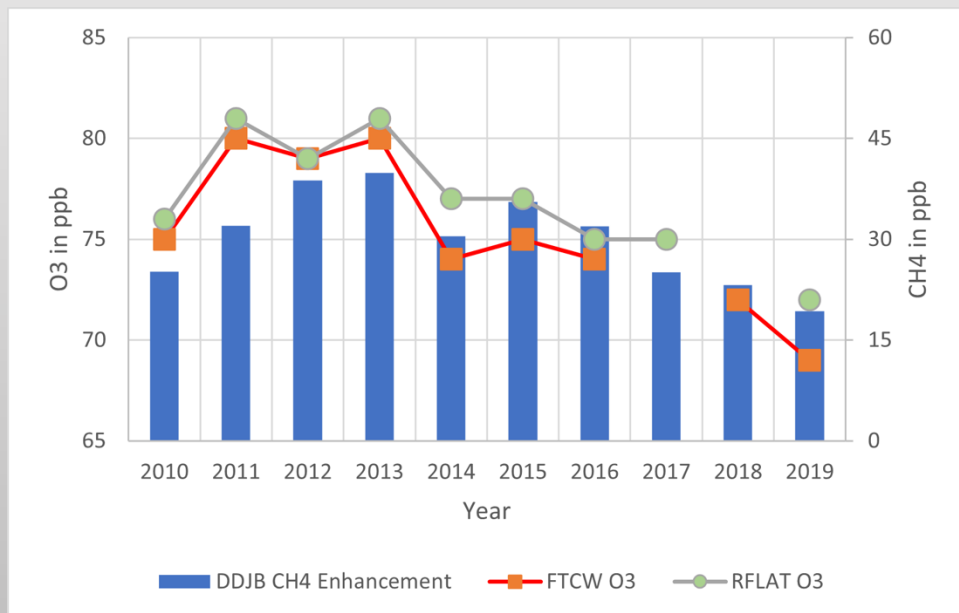
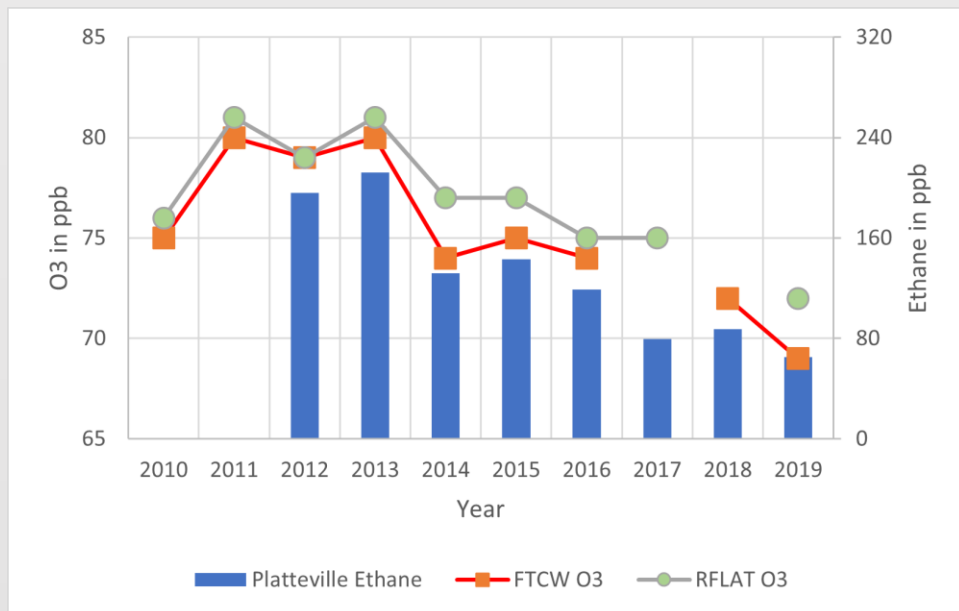


Reddy and Taylor, 2022: <https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2022EA002609>

AIRS CH₄ enhancement and ethane track well with a correlation of 0.96, even on a year-to-year basis; (b) shows year-to year changes).

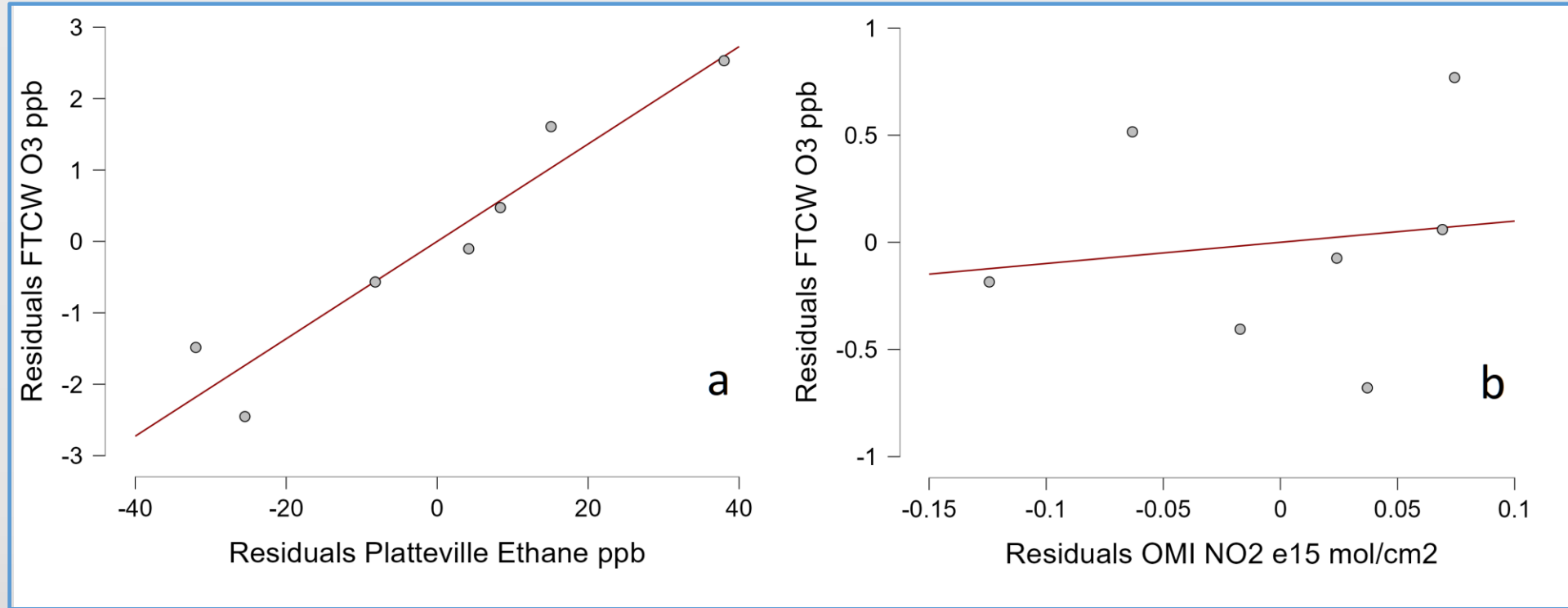


AIRS CH₄ enhancement for the Uintah Basin in Utah (above, using NWR as background) and estimates of CH₄ enhancements from Lin et al. (2021: <https://doi.org/10.1038/s41598-021-01721-5>). These also track well.



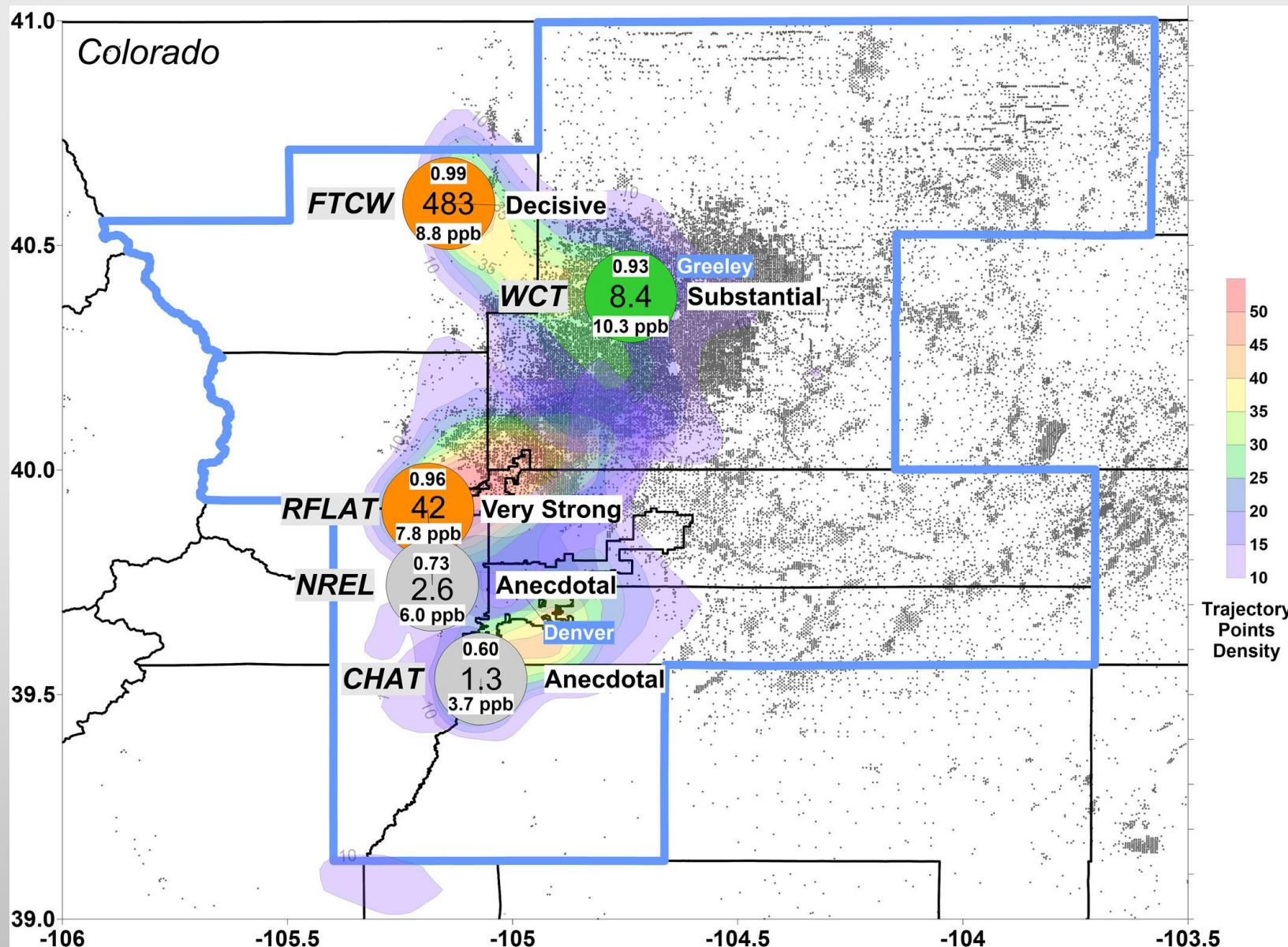
Plots on the left show that Platteville ethane, annual 4th max O₃ at FTCW and RFLAT, and CH₄ enhancement calculated with the AIRS product track well. The plot above shows regressions between the state SIP O&G VOC emissions inventory (Dec., 2022) and Platteville ethane versus the AIRS-derived enhancement.

The VOC inventory and ethane lines zero out at an enhancement that is ~30% of the 2012 value. Petron et al. (2014) show that non-oil and gas sources account for 25% of CH₄ in 2012. (<https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2013JD021272>)



Reddy, 2023: <https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2023EA002917>

- Events flagged for influences from smoke or stratospheric intrusions were removed from the O₃ datasets.
- Partial regression plots, above, suggest that FTCW O₃ is much more sensitive to VOCs (a) than NO_x (b). The correlation between FTCW 4th max O₃ and ethane is 0.99, with a decisive Bayes factor of 483.
- Based on Bayes factors, the probability that ethane (as a tracer for VOCs) is associated with observed reductions in FTCW O₃ is 28 times more likely than a response to NO_x (using OMI NO₂ as a surrogate).



Top to Bottom in Each Circle: **O₃ correlations with Platteville ethane**, Bayesian correlation factor (BF₁₀) values for O₃ and ethane, and O₃ decreases from 2012 to 2019.

The circle colors gray, green, or orange represent Bayesian indications of anecdotal, substantial, or very strong/decisive evidence of an interconnection, respectively.

Monitor footprints for FTCW, RFLAT, and CHAT are plotted. O&G wells are represented by gray dots, and the nonattainment area is outlined in blue.

Conclusions

- Correlations between AIRS CH₄ enhancement and FTCW & RFLAT O₃, the SIP O&G VOC emissions inventory, and ethane range from 0.88 to 0.96 with strong to decisive Bayes factors.
- Reddy and Taylor show reductions of Platteville ethane and AIRS satellite derived CH₄ enhancements for the Front Range region of **~70% and ~50%**, respectively for 2013-2020 (2022: <https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2022EA002609>).
- Corroborating study: Using surface measurements and GOSAT data, Lu et al. show a decline of about 11% per year in CH₄ from O&G production in the Denver Julesburg Basin (DJ Basin) from 2010 to 2019 (2023: <https://doi.org/10.1073/pnas.2217900120>). Their supporting information file yields a **60%** decline in CH₄ from O&G activities in the basin from 2012-2019.
- O&G VOC contributions to annual fourth max O₃ may have declined as much as **~67%** at Fort Collins West and Rocky Flats North from 2012-2019.
- This information could be useful for assessing progress in reducing O₃ and SIP weight of evidence analyses.

Past, present, and potential future uses of satellite data for air quality management in Colorado:

- Forecasting O₃, PM_{2.5}, visibility, and blowing dust
- Health messaging
- Forecasting wildfire smoke
- Exceptional events analyses
- Tracking oil and gas impacts, CH₄ emissions and trends
- O₃ State Implementation Plans and related analyses
- Environmental justice?

Two exciting new uses for satellite data in Colorado:

- Exploring enhanced O₃ forecasting with TEMPO products (Dan Welsh, Katie Broyles, & Scott Landes, CDPHE)
- Tracking air toxics from O&G activities (in response to 2022 Public Protections From Toxic Air Contaminants bill... Ted Russell's Tiger Team?)