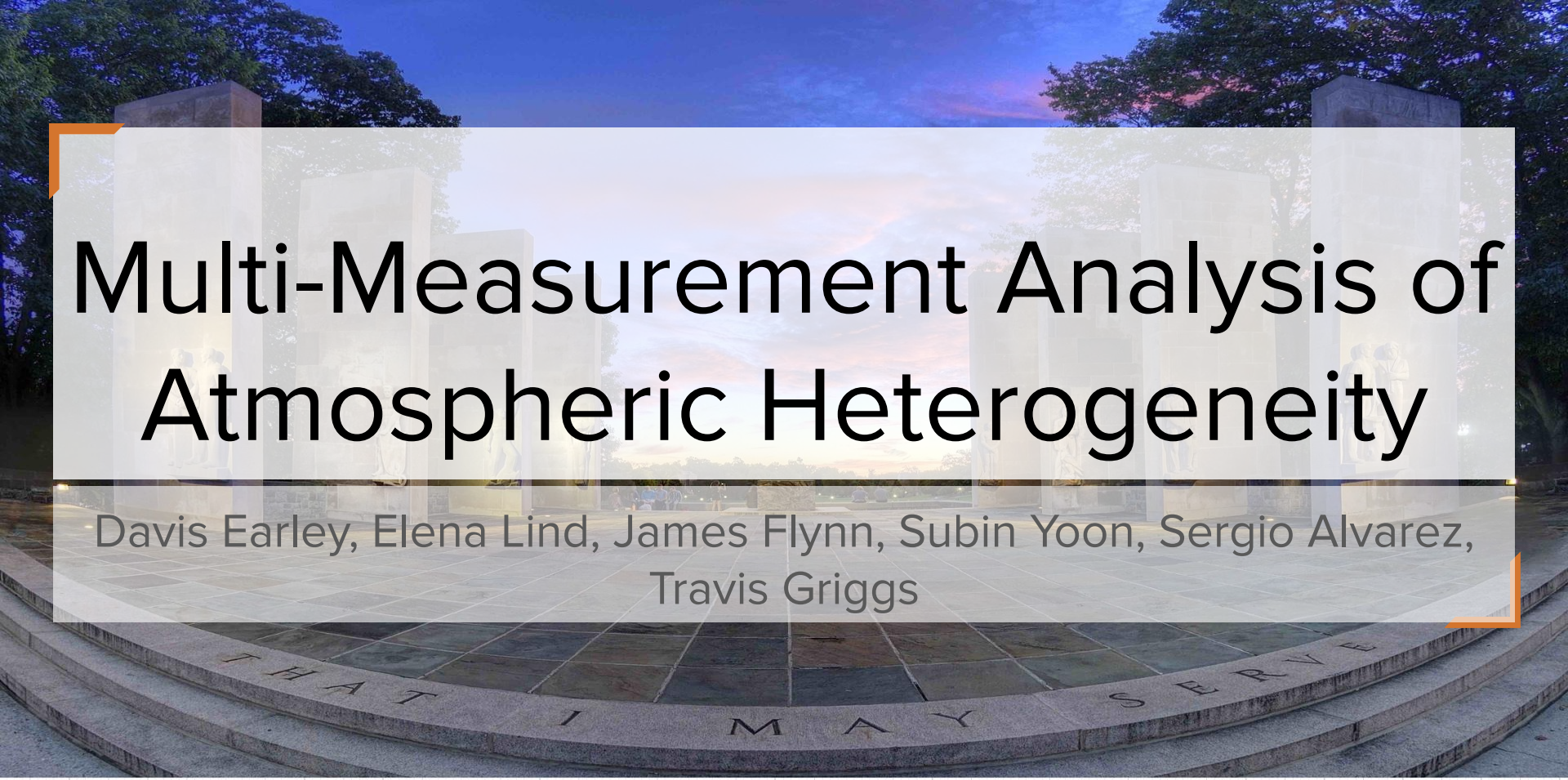

Multi-Measurement Analysis of Atmospheric Heterogeneity

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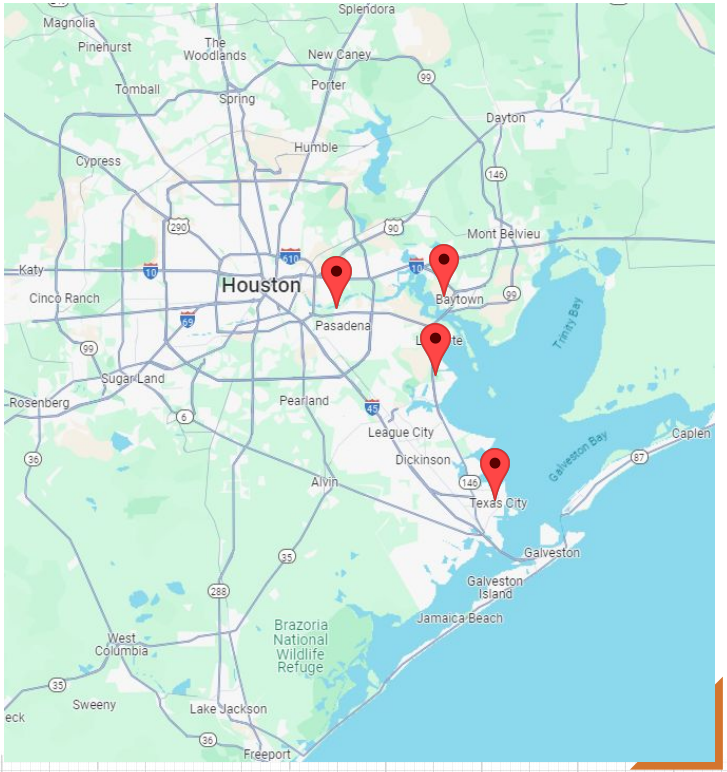
VIRGINIA TECH™

Houston

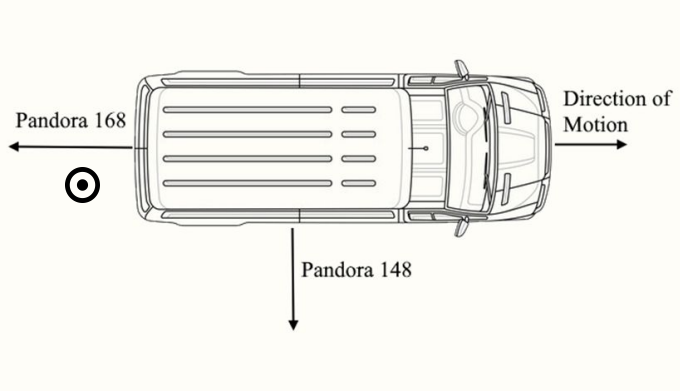
- Largest city in Texas
- Many large refinery complexes
  - Secondary industry making use of oil products
- Large port for exporting oil
- Further industry along coast of Galveston Bay
- TRACER-AQ1/2 (TRacking Aerosol Convection ExpeRiment-Air Quality) : two recent field campaigns held in area
  - Included air quality measurements on land, at sea, and in air during September 2021, 2022
  - Primary interest in NO_2 and HCHO interactions



Data Comparison

- 5 data sets from 4 instruments
  - Pandora data measured directly overhead (Zenith DOAS)
  - 2 Pandora datasets measuring behind and perpendicular to vehicle (MAX-DOAS)
  - In-Situ data collected onboard mobile platform (surface)
  - Boundary Layer height measurements from LIDAR
- TRACER-AQ1: 1 Pandora, focus on relationship between surface concentrations and Vertical Columns from zenith measurements
- TRACER-AQ2: 2 Pandoras, focus on difference in VCD based on measuring direction

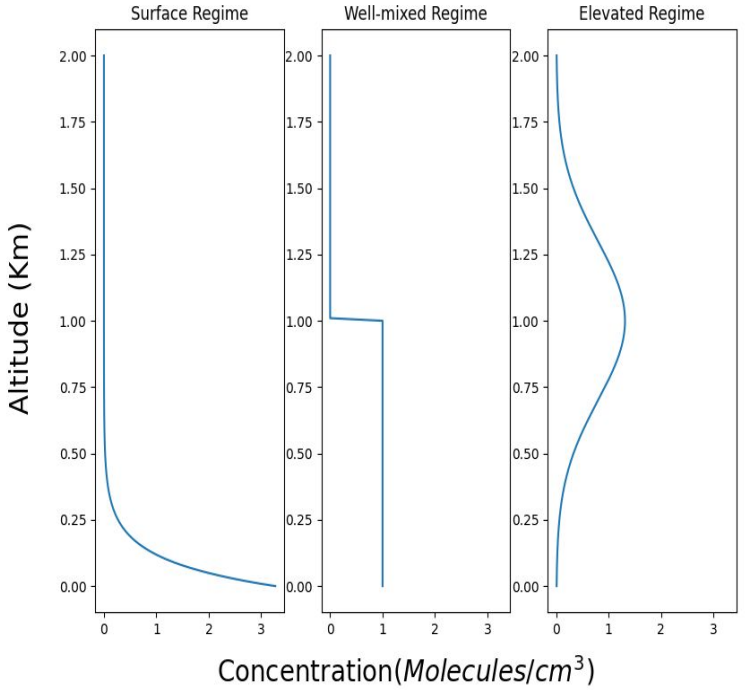
TRACER-AQ2
Pandora Setup



Vertical Heterogeneity

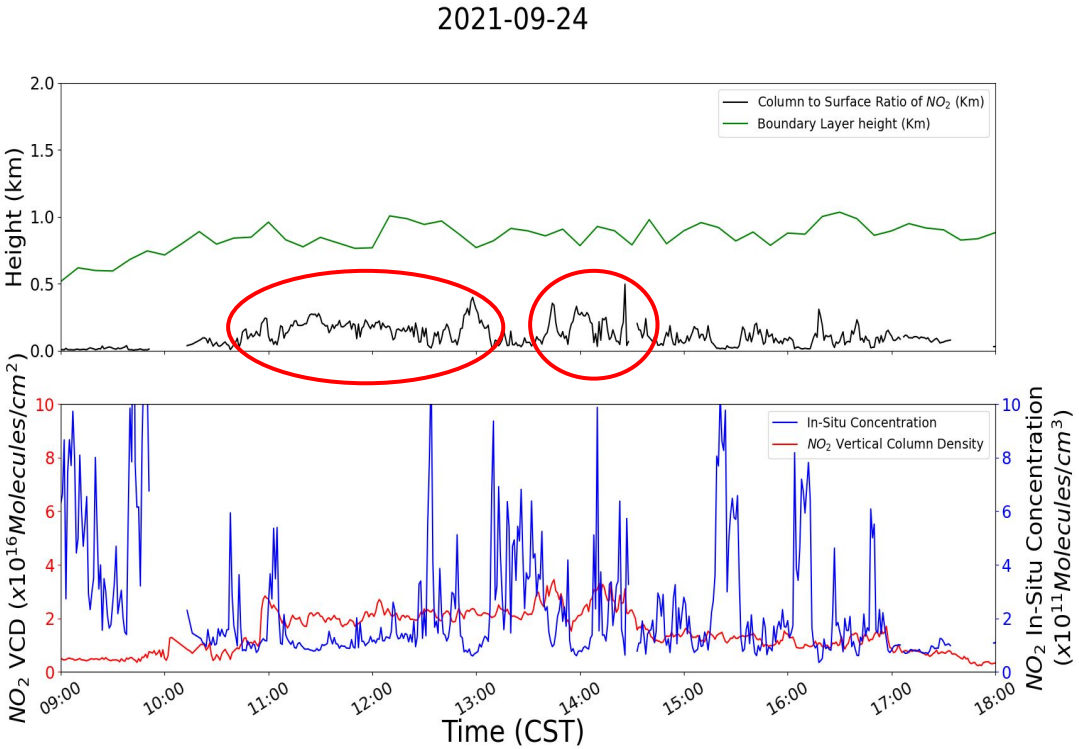
- Column to Surface Ratio
  - Estimates where most of trace gas is located in column
  - Surface, Well-Mixed, and Elevated regimes
- Analysis can be enhanced with comparisons to measurements of planetary boundary layer height

ratio < PBL ratio ~ PBL ratio > PBL



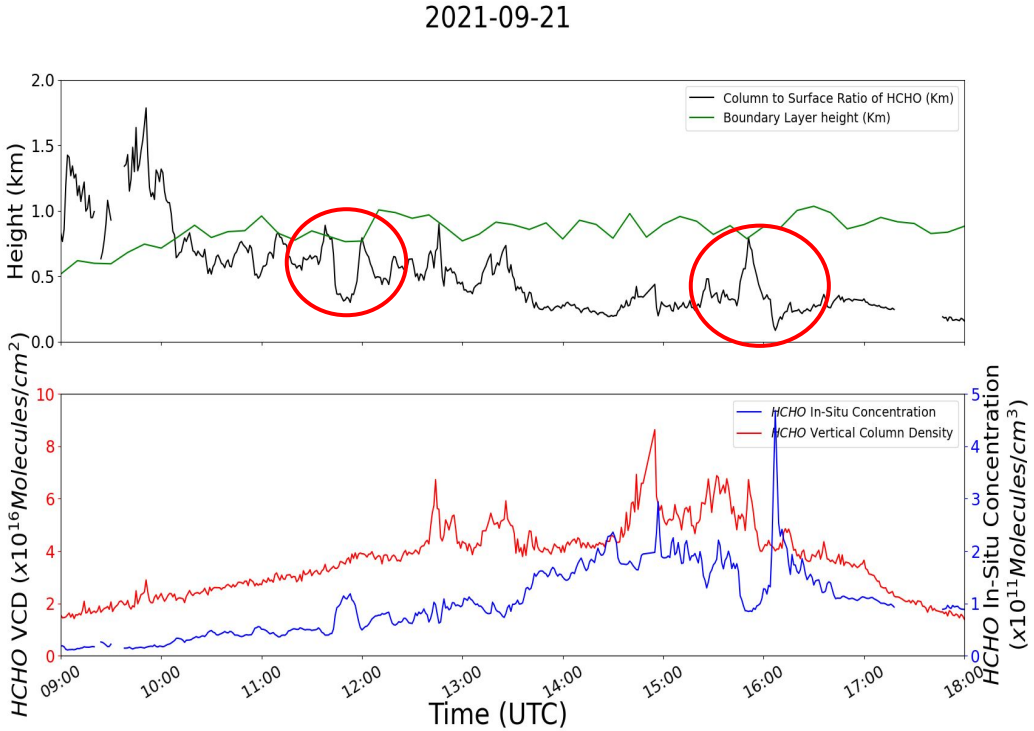
NO_2 Ratios

- NO_2 can be found higher in troposphere close to industry
  - 11:00-15:00 spent in residential areas around Buffalo Bayou
  - NO_2 columns found more elevated in these areas
  - Surface measurements did not register NO_2 present



Formaldehyde Ratios

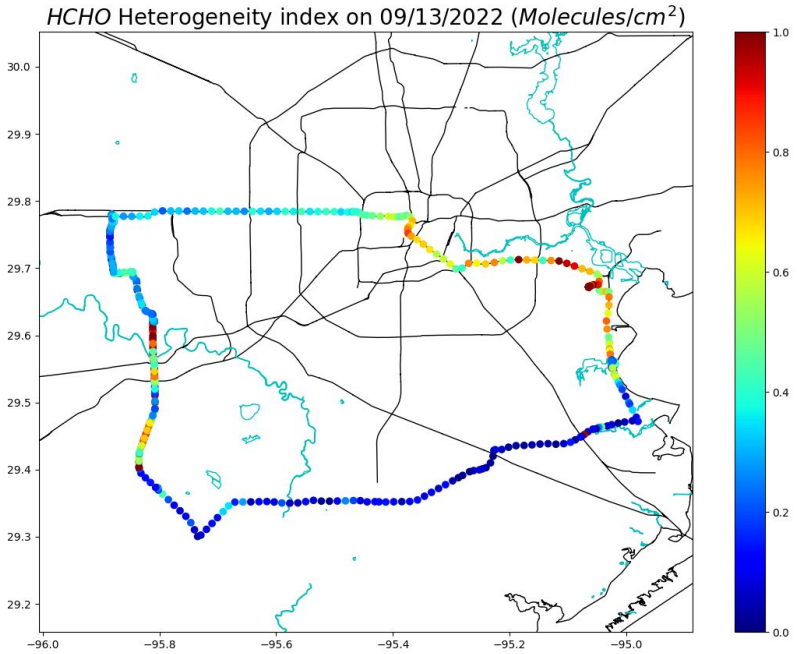
- HCHO typically found at higher altitudes due to longer lifetime
  - Remains well mixed most of day
  - Sudden drops (12:00, 16:00) and peaks (15:30) correspond to industrial areas around Texas City
  - Likely nearby sources present causing large shifts



Horizontal Heterogeneity

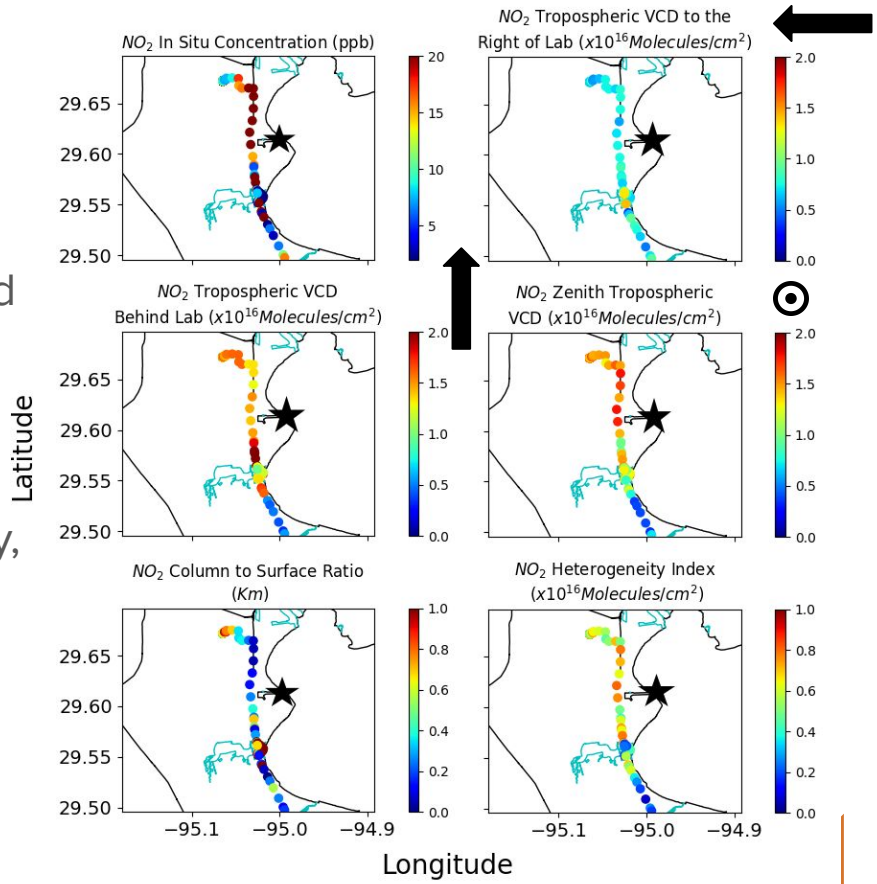
$$H = \sqrt{\frac{\Sigma_{i=1}^{n}(VCD_i - VCD_Z)^2}{n}}$$

- Horizontal heterogeneity Index
  - Comparison between MAX-DOAS VCDs and Zenith VCD
  - Large differences indicate high heterogeneity
- Can estimate horizontal heterogeneity, ID sources, and determine transport within measurement area



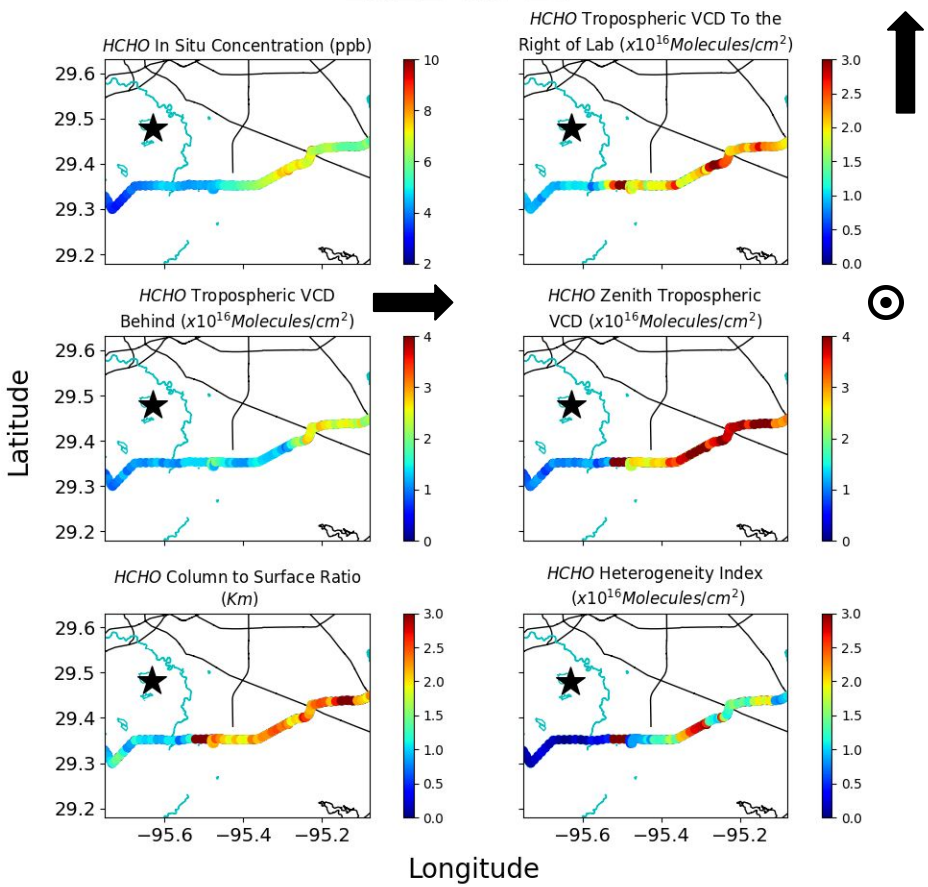
NO_2 around La Porte

- In-Situ detects mostly traffic
- Pandora 148 sees consistent values around Port Authority
- Pandora 168 sees large increase around Port Authority (starred)
- Easterly winds reported for most of the day, however columns are low to the West
  - NO2 emissions likely originating from and confined to the Port of Houston



HCHO South of Houston

- Effect of WA Parish Power plant (starred) noticed by In-Situ
- Comparison of Pandora heterogeneity allows source to be identified
  - Sudden change in VCD difference indicates presence of source to the North
  - 2 distinct areas of high heterogeneity indicate influence of 2 sources



Conclusions

- Column to surface ratio can be used to identify vertical heterogeneity regime
  - Allows for rapid measurement of vertical heterogeneity
  - Useful for use on mobile platforms
- Horizontal heterogeneity analysis is able to identify prominent sources and describe contribution of transport over measurement area
  - Comparisons of remote sensing measurements in multiple directions obtains a greater understanding of trace gas distribution over a larger area