

Investigation of a Pollution Plume Observed by the NASA C-23 Sherpa Aircraft during the 2017 OWLETS Campaign

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Outline

- Brief overview of OWLETS-1
- Motivation
- Observation of Species Variability
- July 20, 2017 Case Study
- CO/CO₂ Ratios
- Conclusions
- Future Work
- Acknowledgements

OWLETS-1

- Conducted over the Chesapeake Bay and Hampton Roads region from July 5-August 3, 2017
 - 12 measurement days
- Measurements were conducted at two research sites (CBBT and LaRC)
 - CBBT: over-water; LaRC: over-land
 - Equipped with a combination of lidar, balloon-borne measurements and aerosol profiling
- Mobile measurements (aircraft, ship, vehicular, and UAV) were collected between the two sites to directly observe pollutant gradients and understand the processes occurring at the land-water interface (Sullivan et al., 2018)

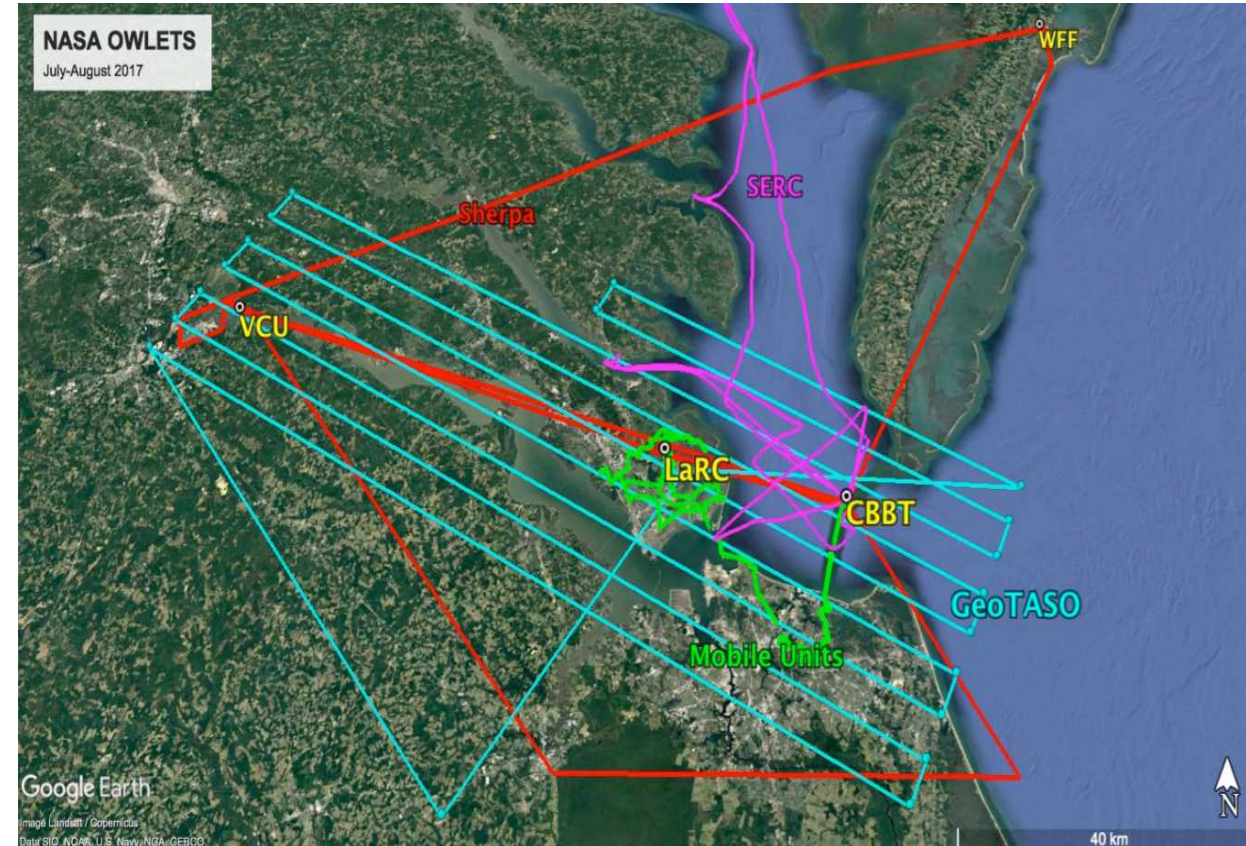


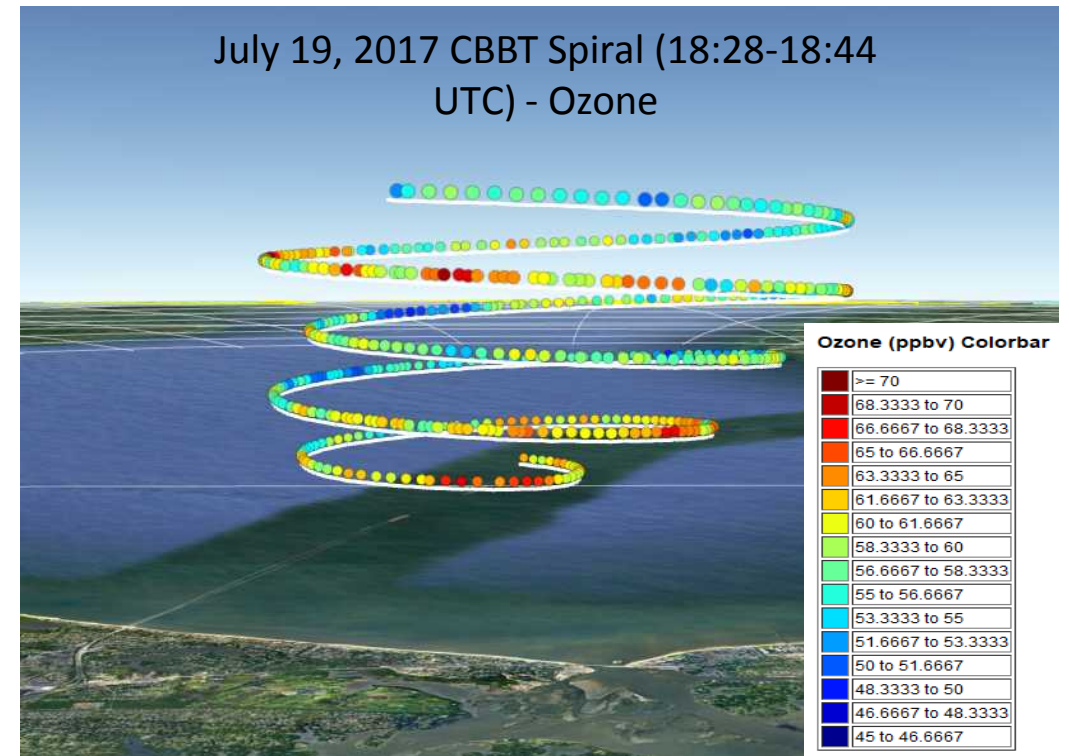
Image Courtesy: Sullivan et al., 2018

Motivation

- Examine spatial variability of pollutants (Ozone, NO, NO₂, CO, CO₂, CH₂O) over water
 - How will this variability affect current and future satellite measurements (TROPOMI, TEMPO)?
 - How to best characterize this variability?
- What's causing pollution gradients in coastal environments, such as the Chesapeake Bay?
- Utilize aircraft data to examine spatial variability over the Chesapeake Bay

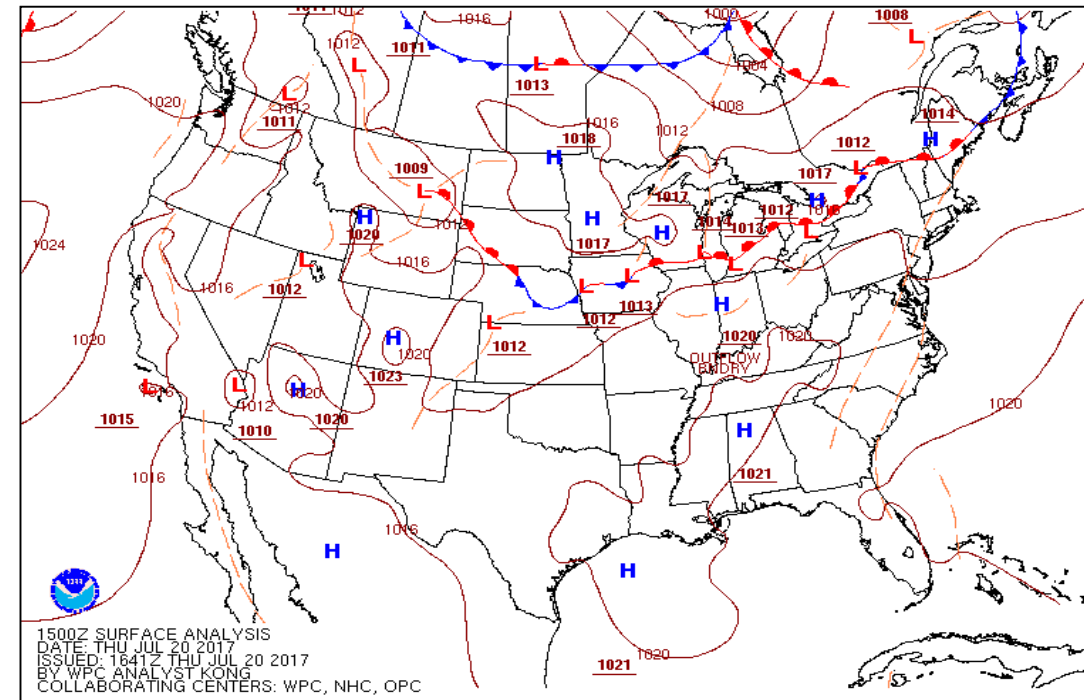
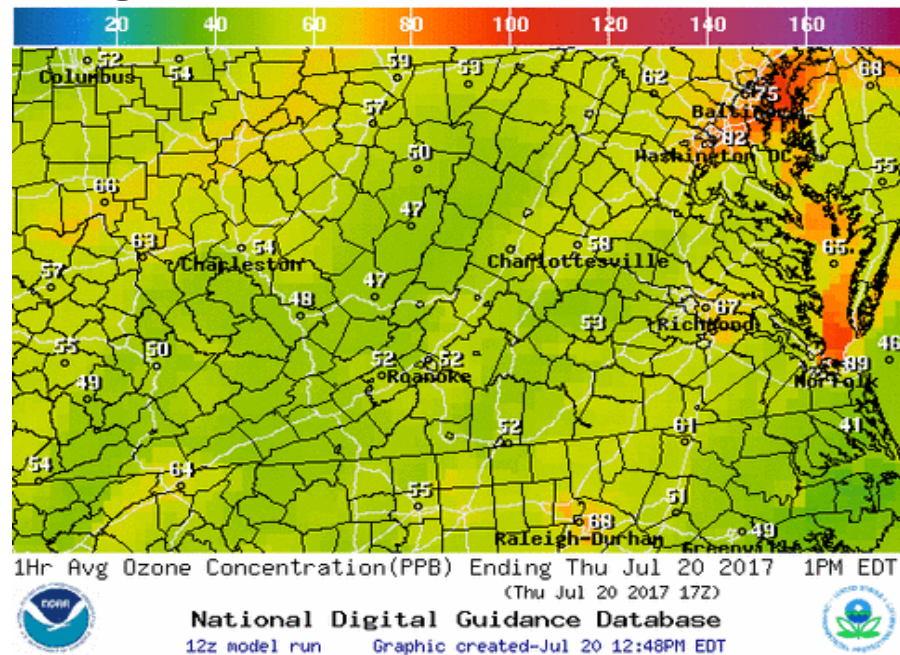
Observation of Species Variability

- **NASA's C-23 Sherpa aircraft** conducted two days of measurements during OWLETS-1 on July 19 and July 20, 2017 over the Hampton Roads and Chesapeake Bay region
 - Overpasses and spirals were completed over Richmond, NASA LaRC (Hampton), CBBT, and Wallops Island
 - Equipped with an in-situ air quality payload
- Initial analysis reveals high amount of variability over water during the spirals conducted over the CBBT
 - Species include: O_3 , NO, NO_2 , CO, CO_2 , and CH_2O
- Species variability highlighted during a plume event on July 20, 2017

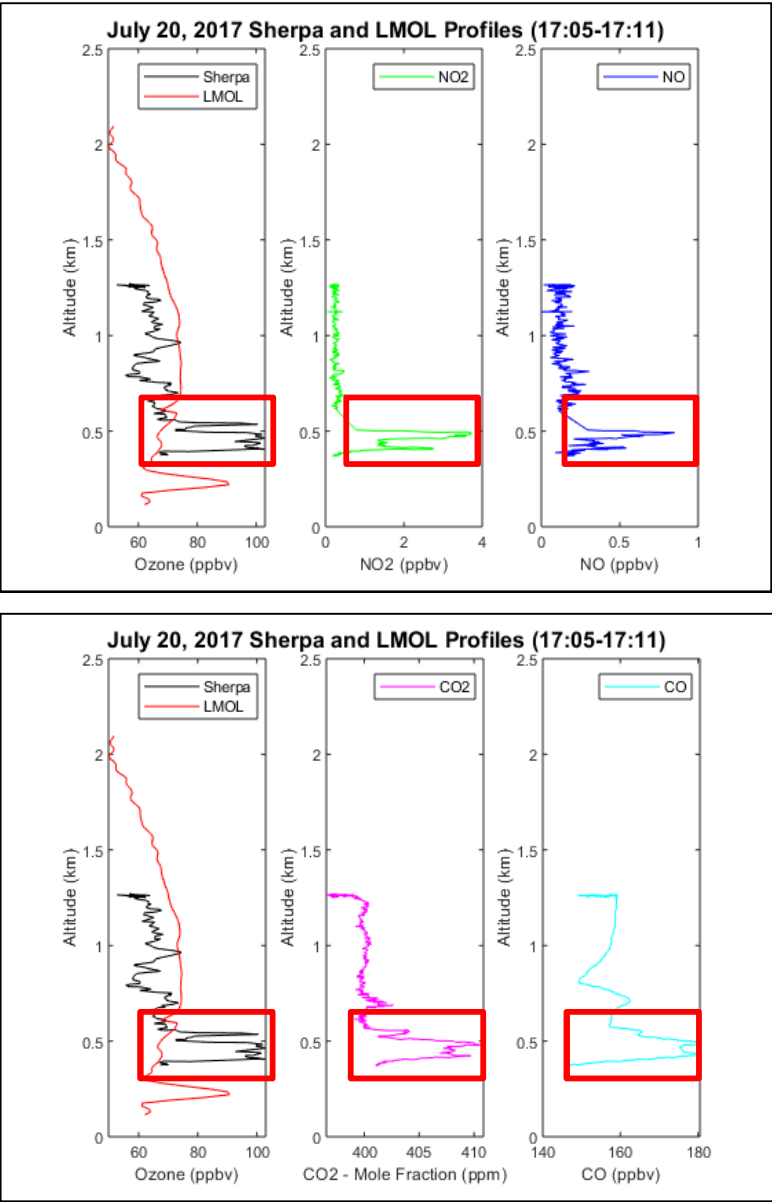
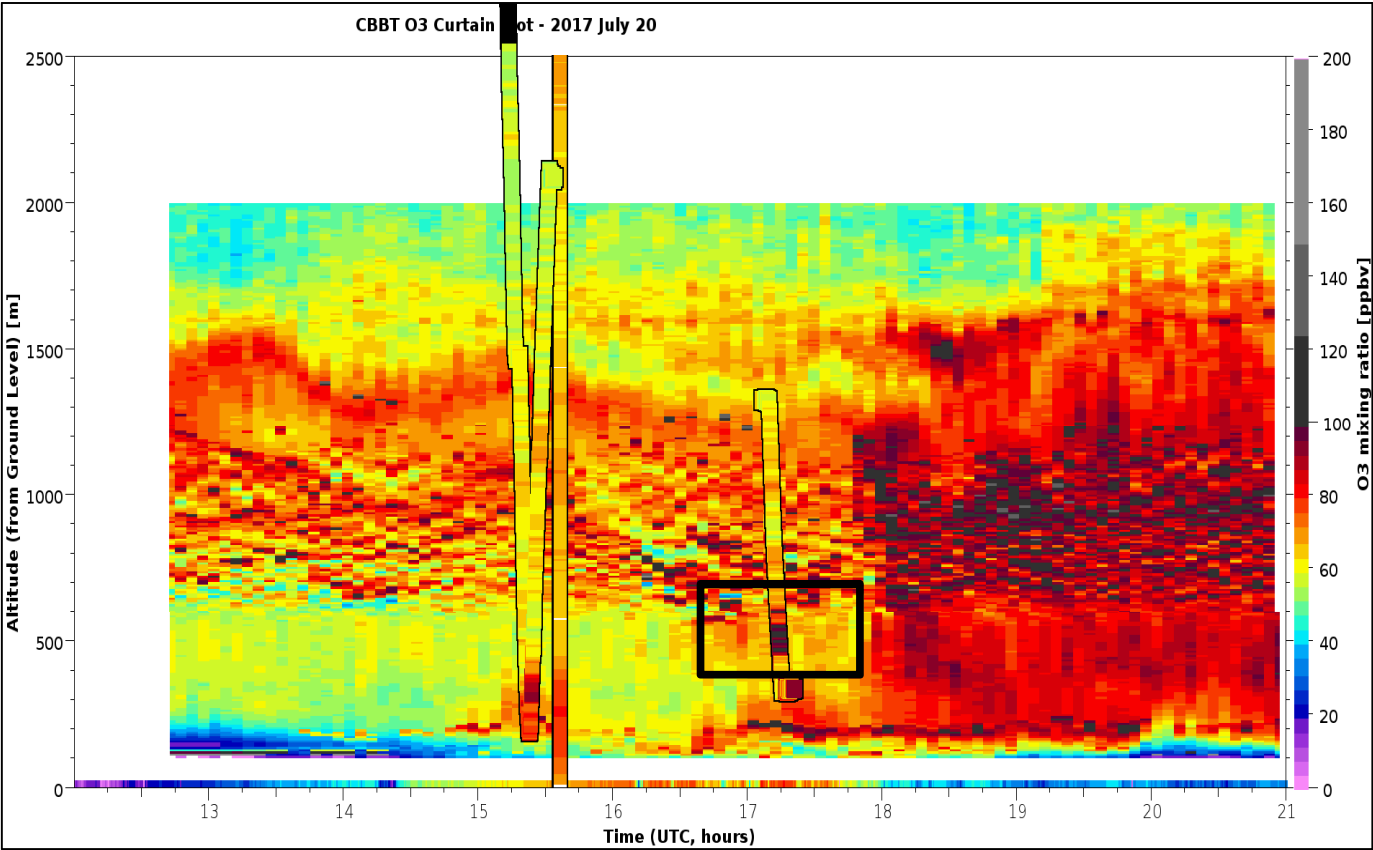


July 20, 2017 Case Study

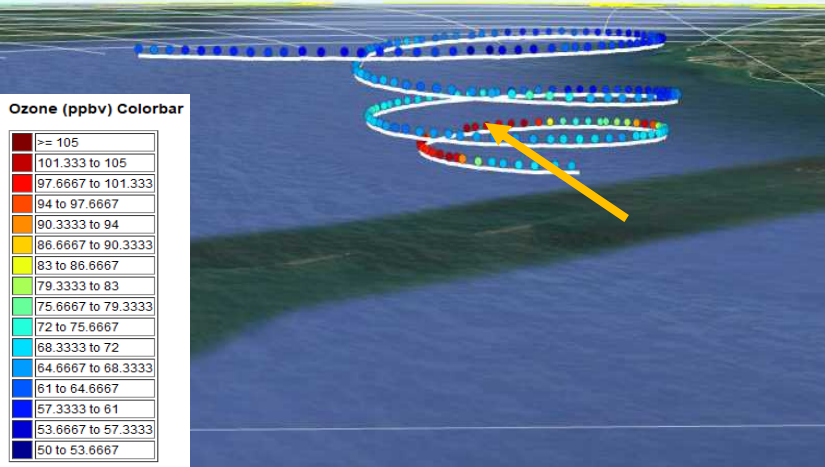
- Area of high pressure situated over the Southeastern United States
 - Temperatures reached the low-mid 90's with Dew Points climbing into the mid 70's
- Ozone values forecasted to reach >100 ppb over the Chesapeake Bay during the afternoon and evening



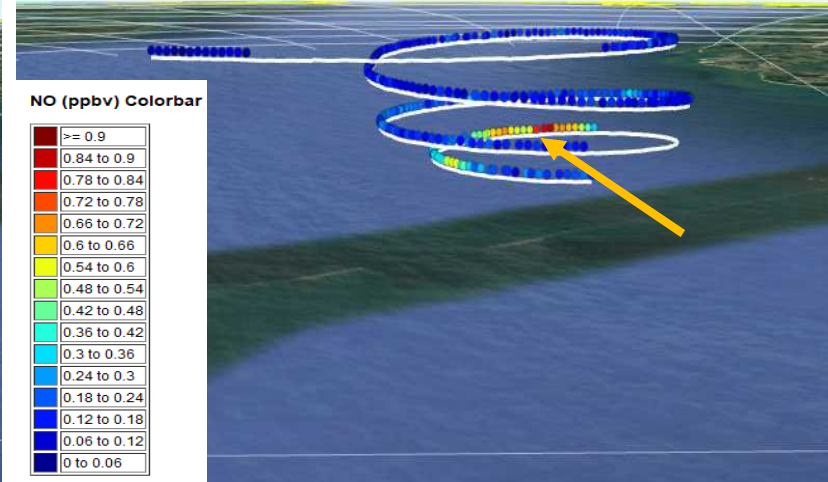
C-23 Sherpa aircraft profile conducted over the CBBT between 17:05-17:11 UTC revealed an elevated species layer, including O₃, NO, NO₂, CO, and CO₂



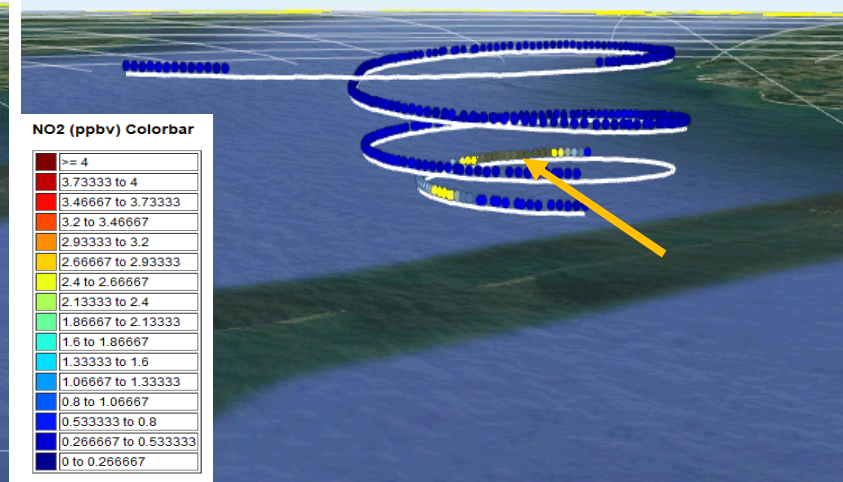
July 20, 2017 CBBT Spiral
(17:05-17:11 UTC) - Ozone



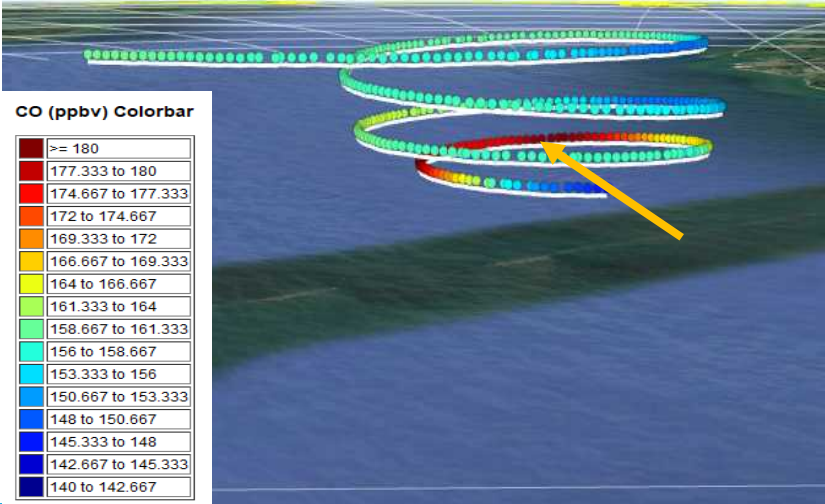
July 20, 2017 CBBT Spiral
(17:05-17:11 UTC) - NO



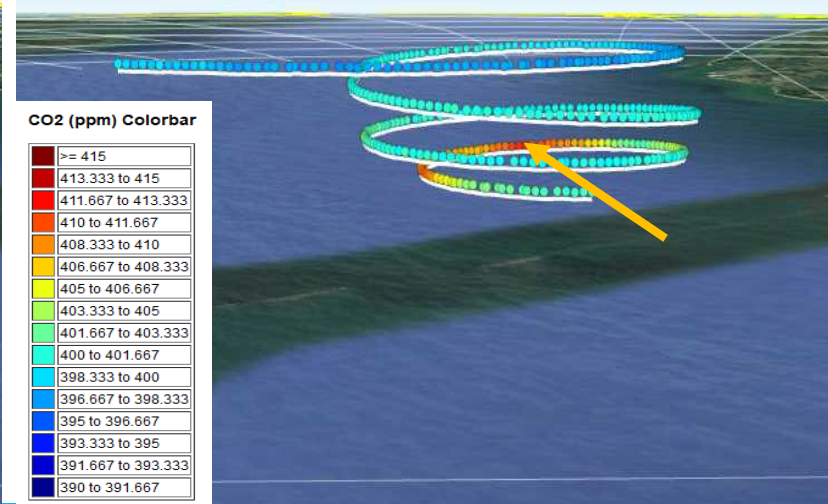
July 20, 2017 CBBT Spiral
(17:05-17:11 UTC) - NO₂



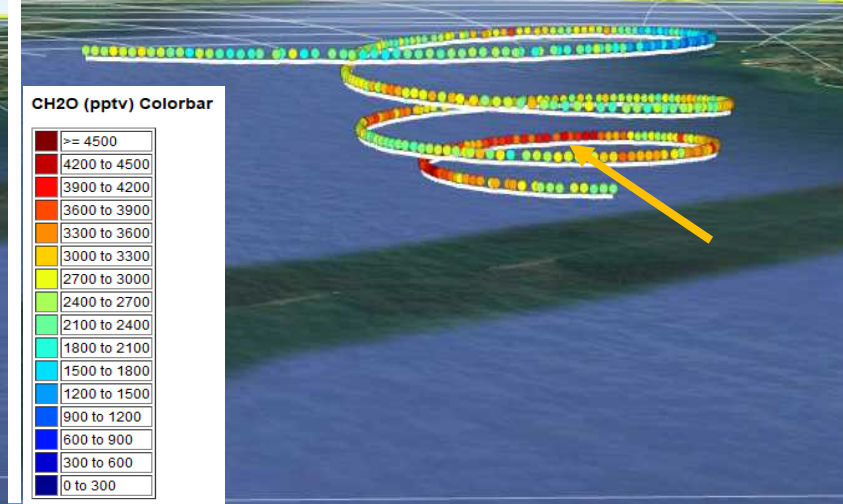
July 20, 2017 CBBT Spiral
(17:05-17:11 UTC) - CO



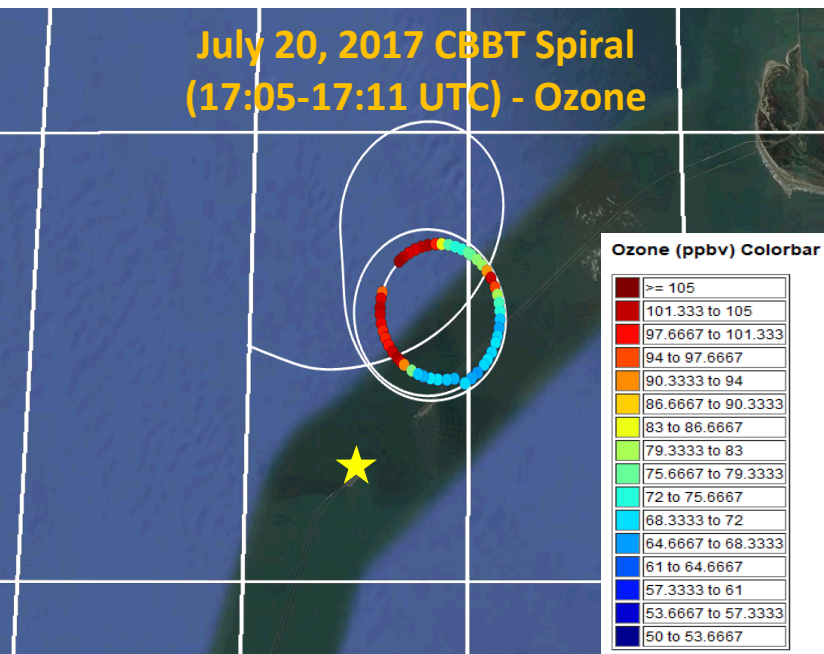
July 20, 2017 CBBT Spiral
(17:05-17:11 UTC) - CO₂



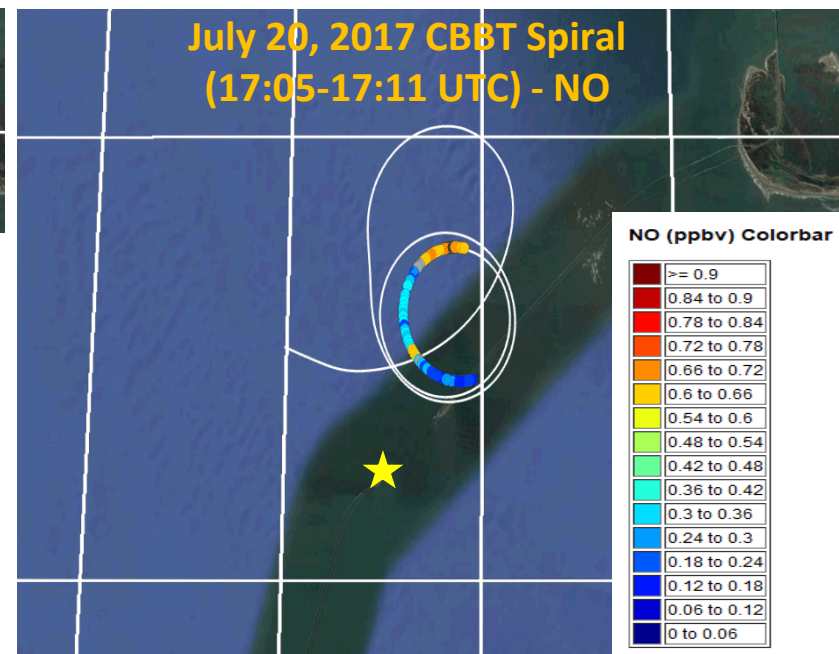
July 20, 2017 CBBT Spiral
(17:05-17:11 UTC) - CH₂O



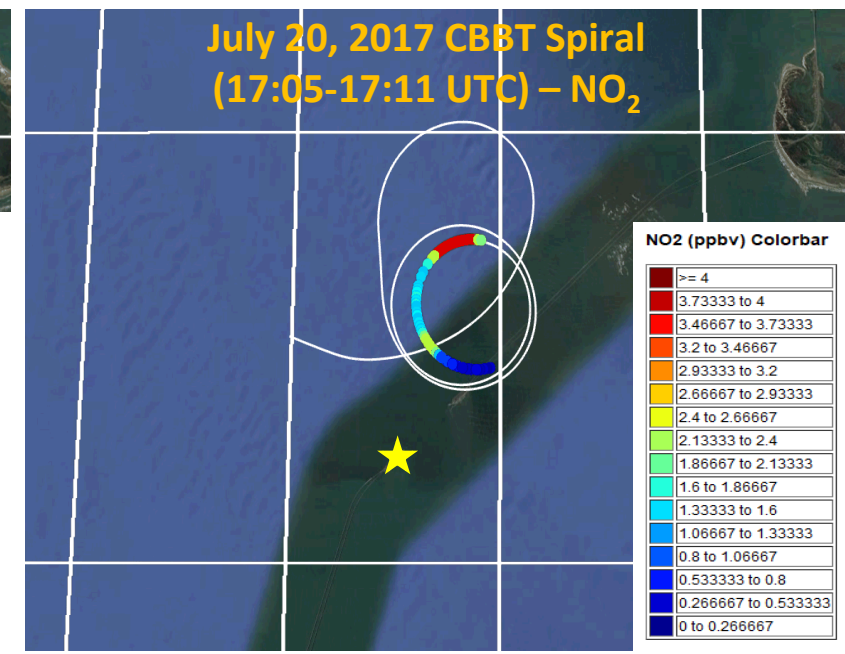
July 20, 2017 CBBT Spiral
(17:05-17:11 UTC) - Ozone



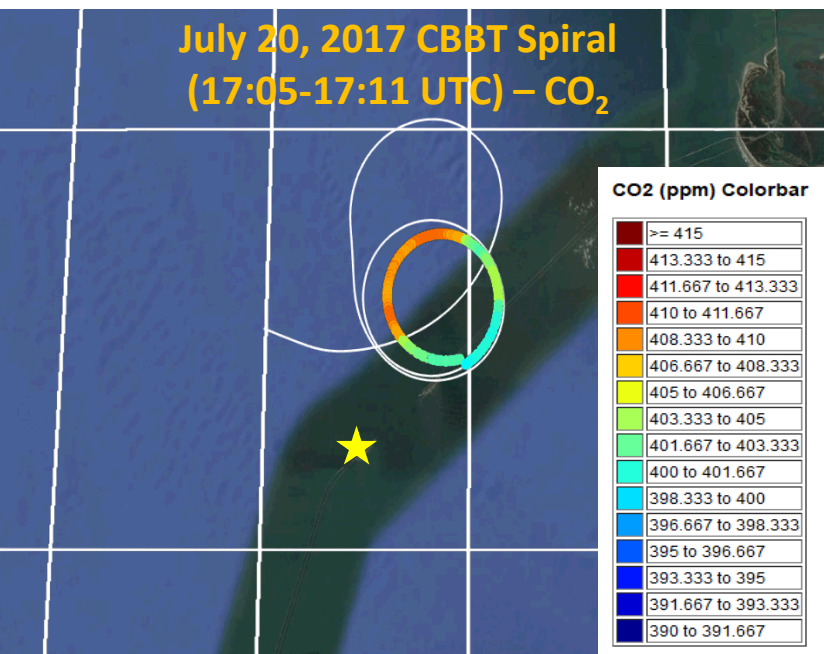
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(17:05-17:11 UTC) - NO



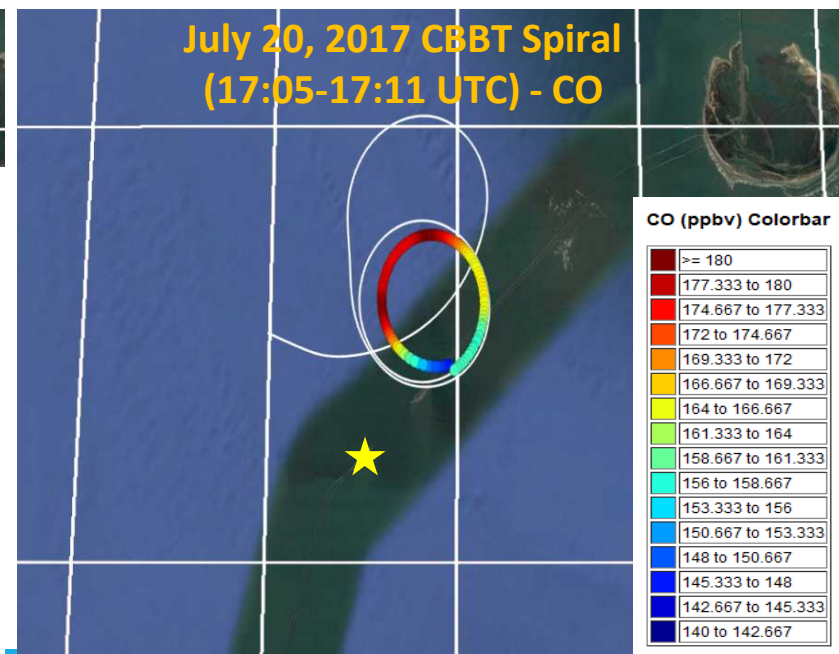
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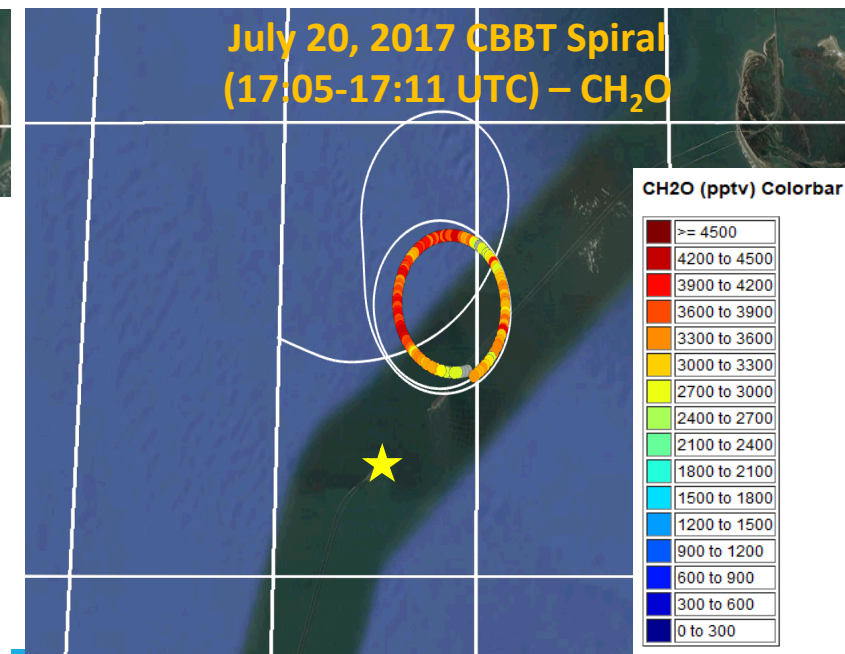
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(17:05-17:11 UTC) - CO₂

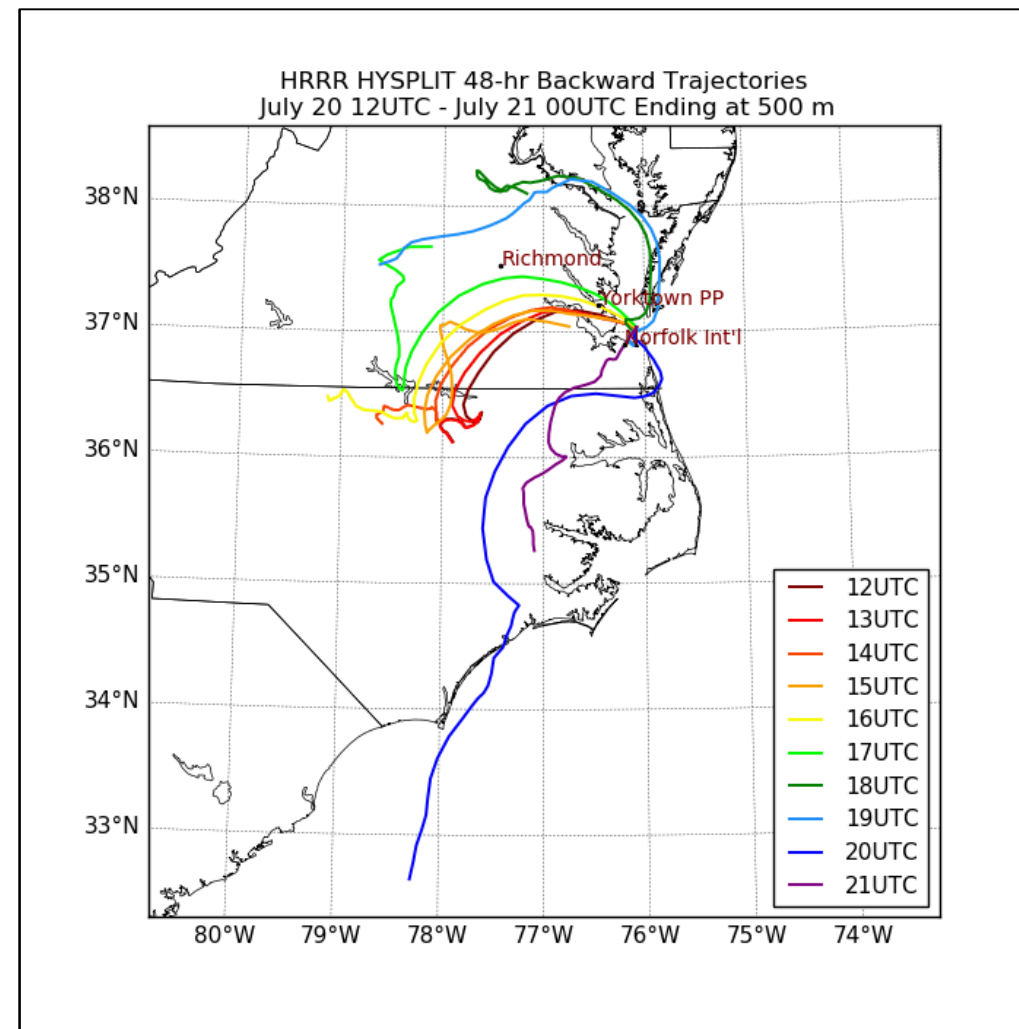
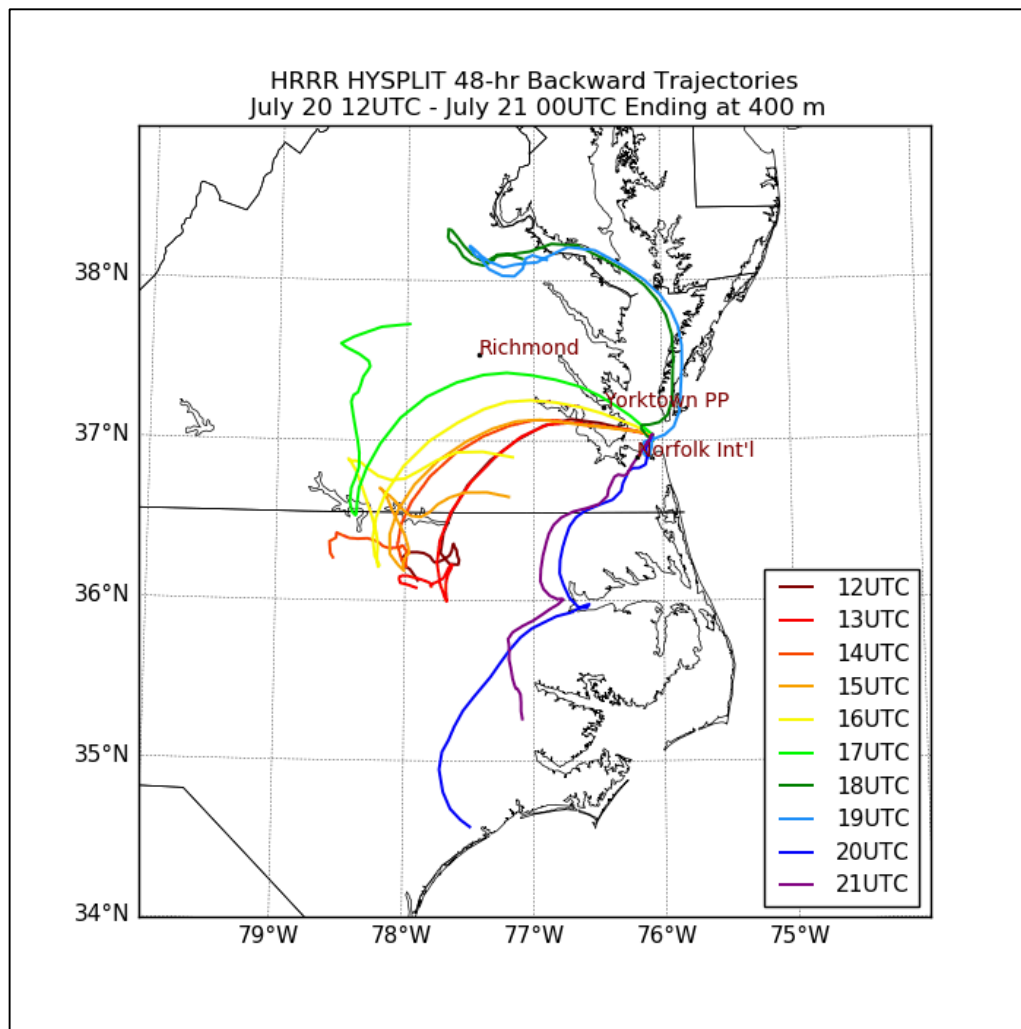


July 20, 2017 CBBT Spiral
(17:05-17:11 UTC) - CO



July 20, 2017 CBBT Spiral
(17:05-17:11 UTC) - CH₂O

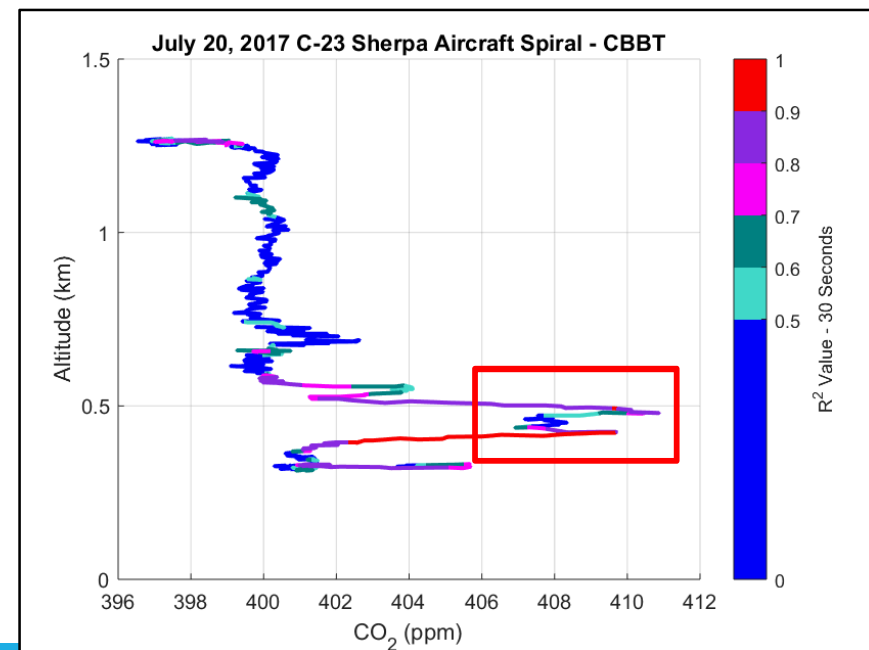
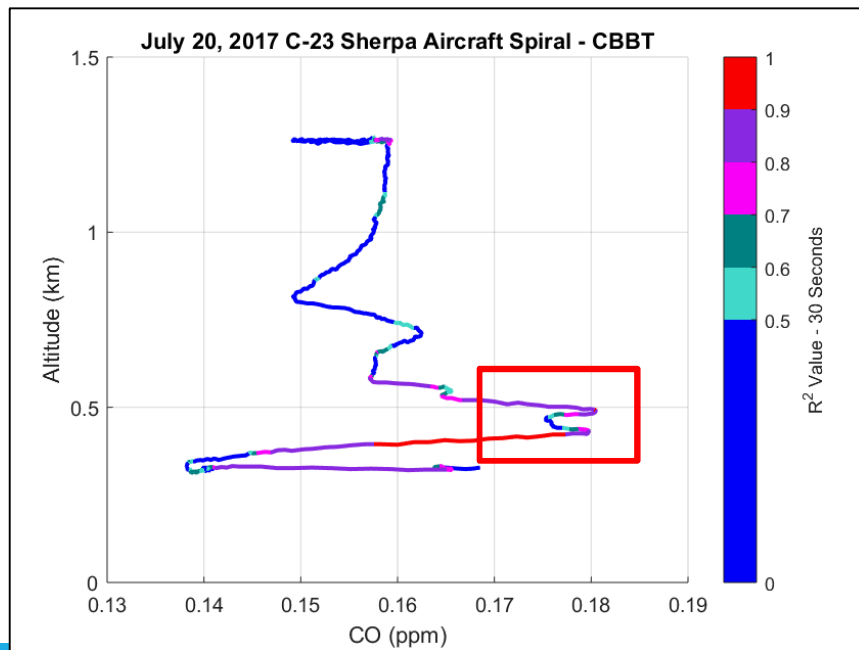
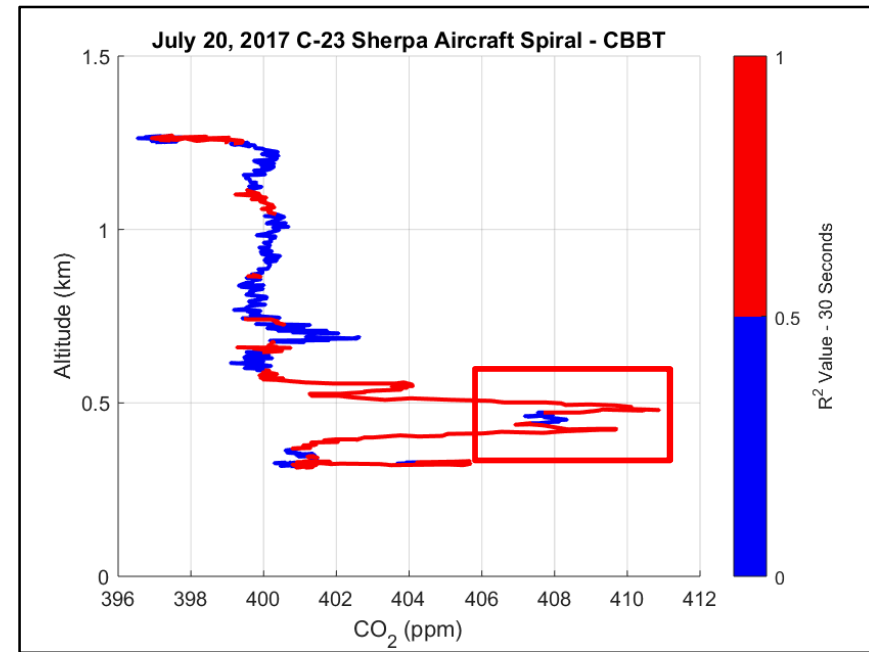
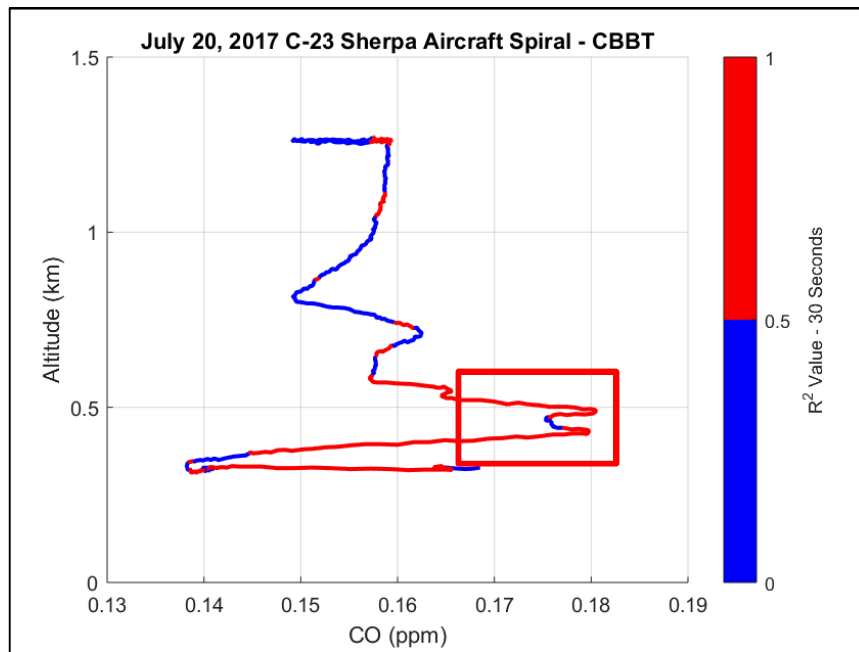


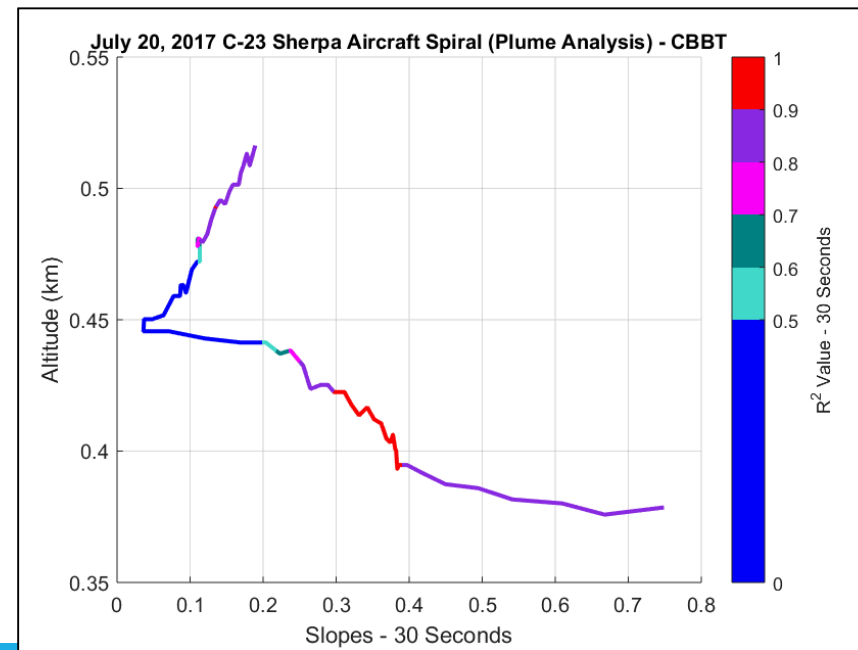
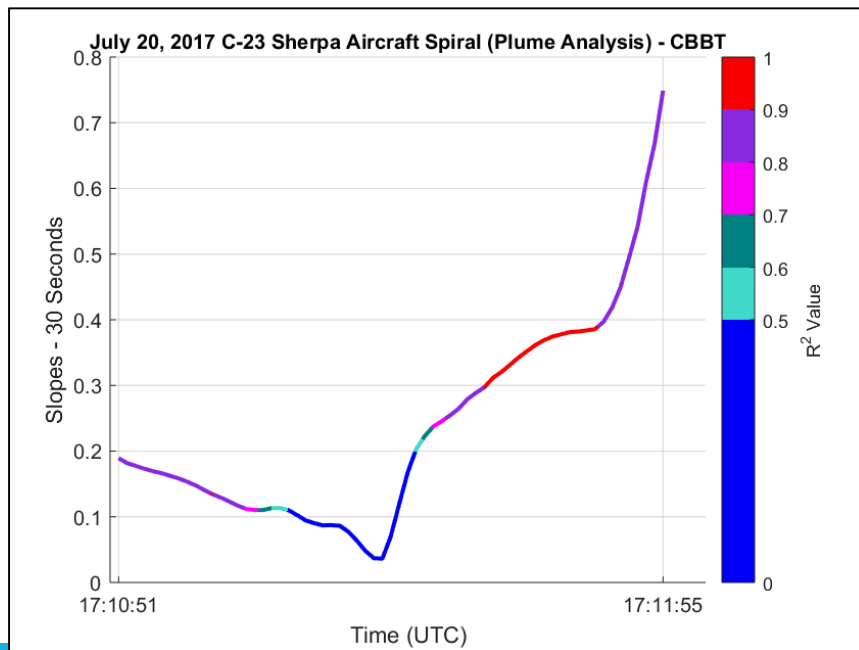
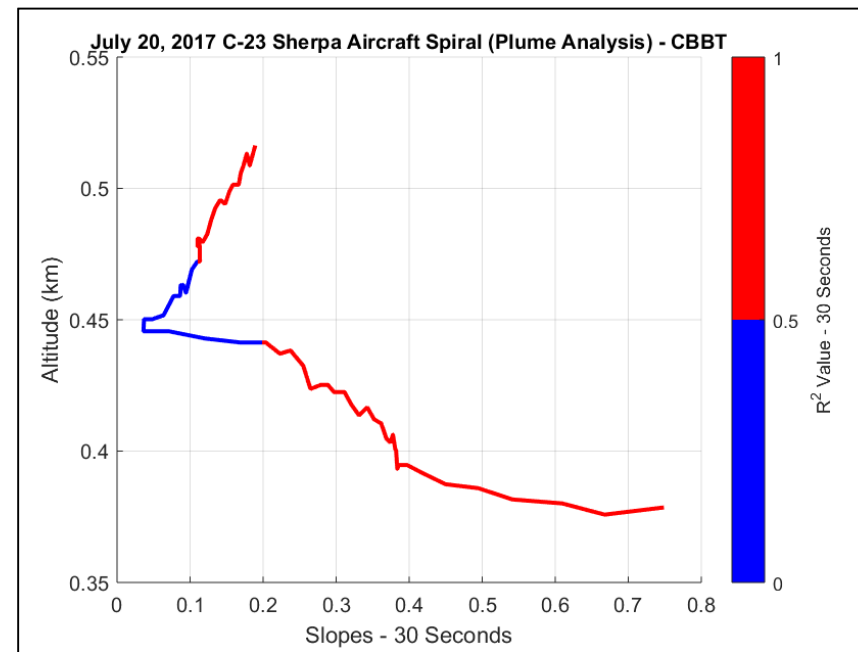
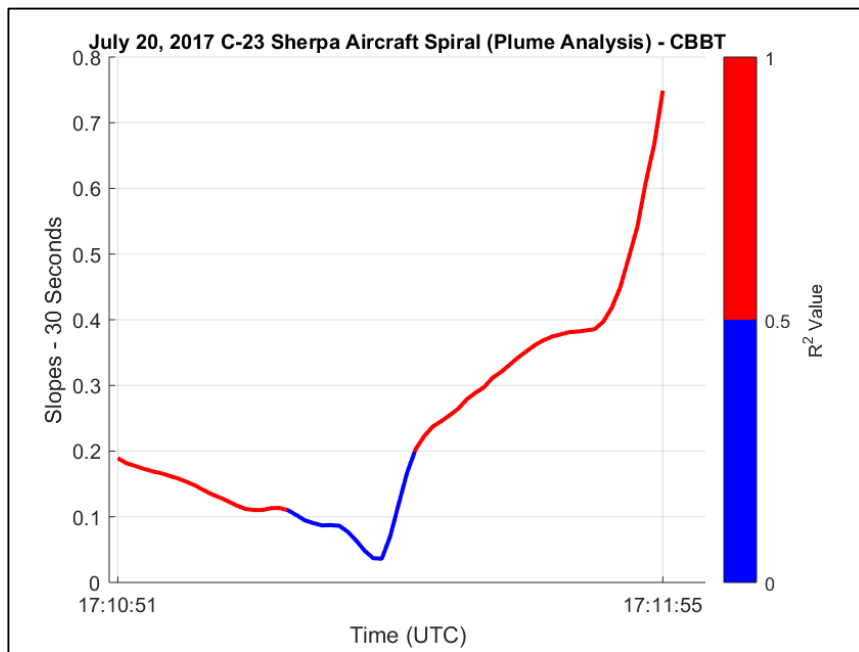


For further analysis on HYSPLIT and model sensitivity, visit Rodio et al., Poster #1056, currently on display in the Poster Hall!

CO/CO₂ Ratios

- Method utilized in Halliday et al. 2019 (in prep)
 - Ratio of CO to CO₂ provides information about the types of combustion occurring in a region (biomass, power plant, etc.)
 - Two different rolling windows (30 and 60 seconds) ran over each flight
 - Slopes were calculated using weighted linear regressions
 - Correlation Coefficients
 - Slopes are reported as percentage values (ppm/ppm *100)
- Simplistic interpretation of combustion efficiency
- Analysis highlights 30 second window
- Typical slope ranges used in this analysis:
 - Power plant: 0-0.1%
 - Vehicle: 0.5-2%
 - Industry: 2-6%
 - Biomass: 7-12%





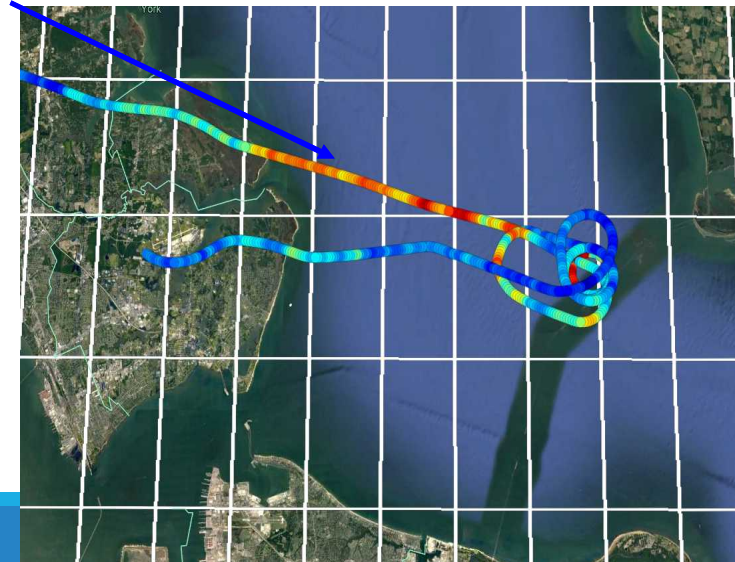
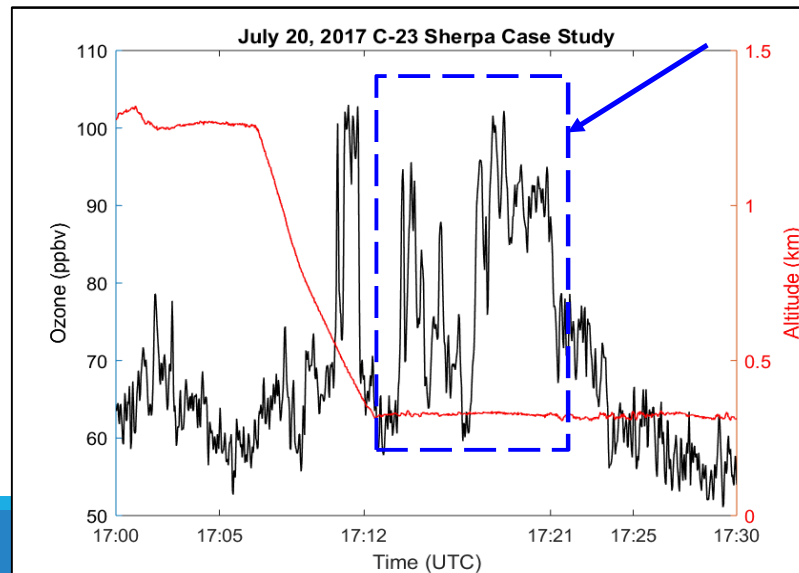
Conclusions

- Analysis indicates that the plume is potentially made up of two different/sources
- CO/CO₂ ratio analysis indicates that some of combustion sources may have been vehicular/power plant sources
 - Back trajectories at the time of the spiral indicate a parcel path over Yorktown Power Plant
- CO/CO₂ analysis has proven to be a viable technique in analyzing combustion sources
- High spatial variability could pose challenges for future satellite pixel sizes
 - Plume is located within one TEMPO pixel

Future Work

- Further analysis on CO/CO₂ ratios
 - Initial analysis revealed a distinct change in slopes over land vs. over water
- Best way to characterize variability seen in the aircraft data over water?
- What causes the observed variability?
 - How does the high amount of ship traffic affect pollutants over the Chesapeake Bay?

Straight leg low over water

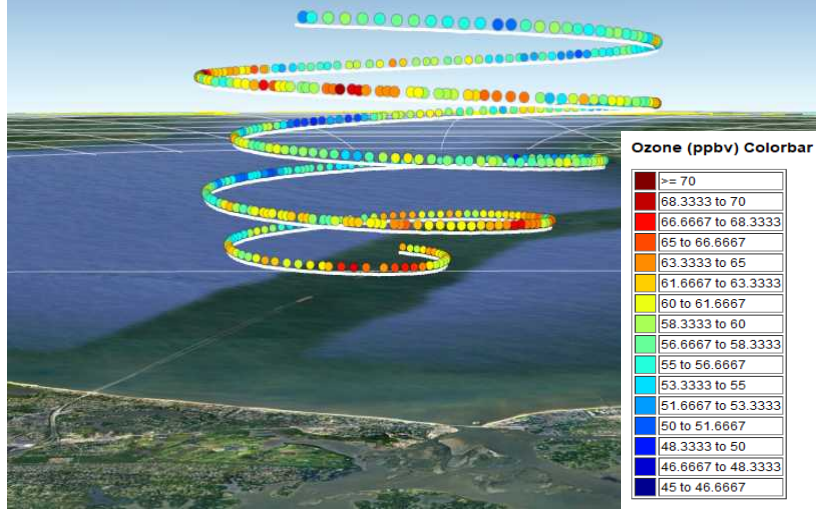


Acknowledgements

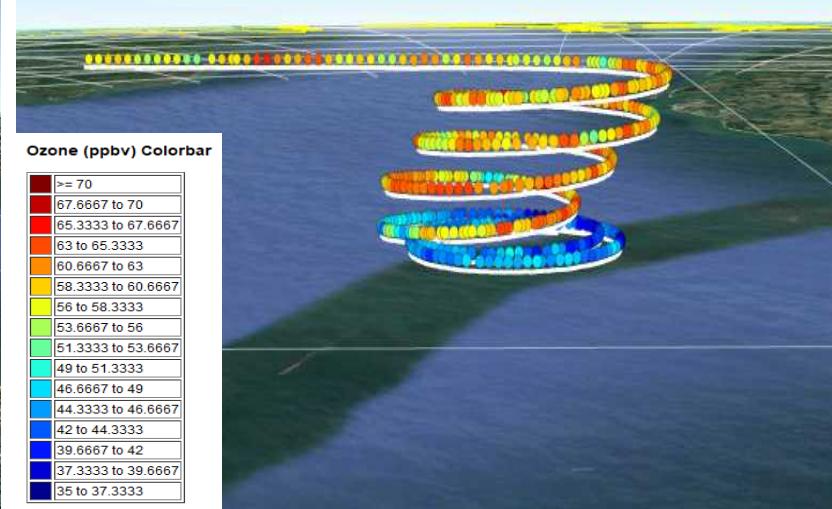
- Amy Jo Scarino – SSAI
- Margaret Pippin – NASA LaRC
- John Sullivan – NASA GSFC
- Sally Pusede, Thomas Hanisco, James Flynn, Donald Blake, Melissa Yang (C-23 Sherpa Aircraft Instrument PI's)
- C-23 Sherpa Aircraft flight crew
- STARSS III
- 2017 NASA Science Innovation Fund, NASA Tropospheric Composition Program, TEMPO Student Collaboration Project, Tropospheric Ozone Lidar Network (TOLNet)

Backup Slides

July 19, 2017 CBBT Spiral
(18:28-18:44 UTC) - Ozone

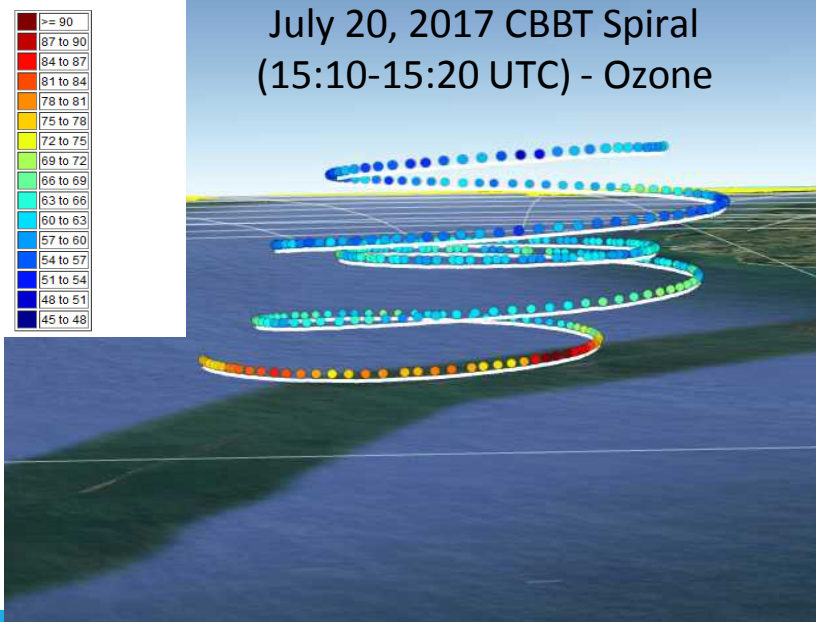


July 19, 2017 CBBT Spiral
(20:28-20:43 UTC) - Ozone

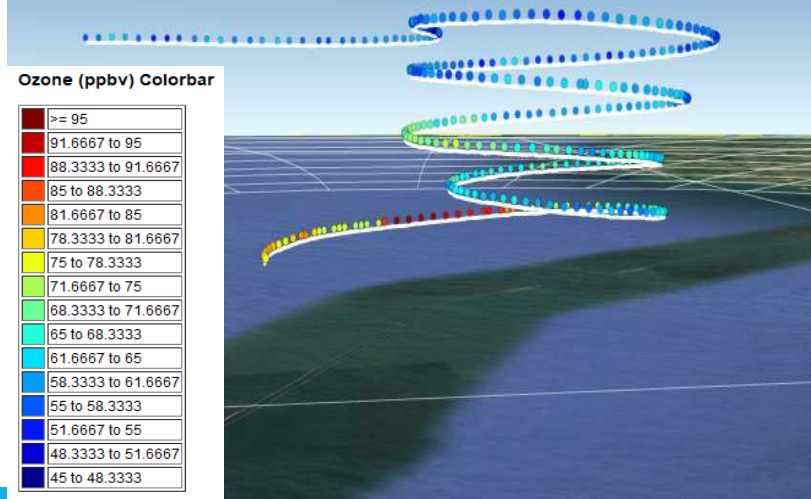


Ozone (ppbv) Colorbar

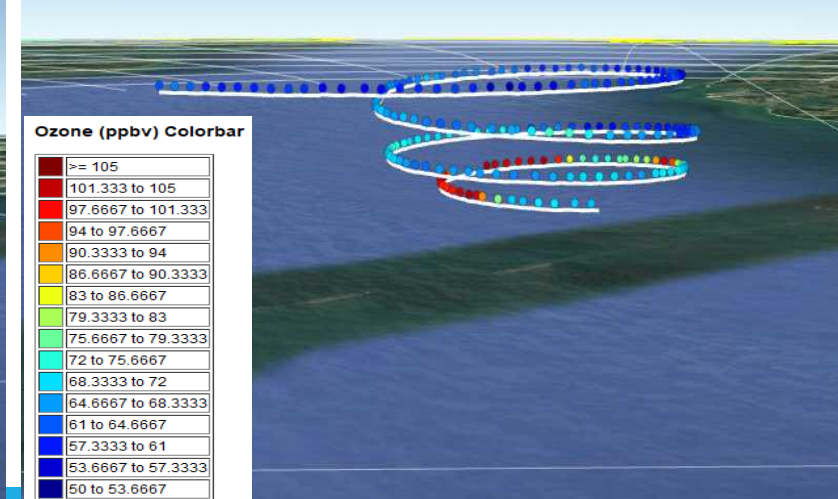
July 20, 2017 CBBT Spiral
(15:10-15:20 UTC) - Ozone



July 20, 2017 CBBT Spiral
(15:20-15:30 UTC) - Ozone



July 20, 2017 CBBT Spiral
(17:05-17:11 UTC) - Ozone



High-Resolution Rapid Refresh model

- Real-time 3-km resolution, hourly updated, cloud-resolving, convection-allowing atmospheric model
 - Initialized by 3 km grids with 3 km radar assimilation
 - Radar data is assimilated every 15 minutes over a 1-hr period adding more detail to that provided by the hourly data assimilation from the 13 km radar-enhanced Rapid Refresh

CO/CO₂ Ratios – More information

- Provides information about the kinds of combustion occurring in a region, as most of the CO measured in the atmosphere is sourced from combustion (open air fires or in engines)
- Ratio can be used as a tracer as CO and CO₂ generally have common combustion sources with specific emission ratios
 - CO has an OH oxidation lifetime of approx. two months (good tracer for synoptic scale transport)
 - CO is predominantly produced by incomplete combustion of carbon containing fuel
 - During high efficiency combustion, fuel carbon is converted to CO₂ with nearly perfect efficiency (low ratios)
 - Low efficiency combustion (i.e. smoldering processes, biomass burning) yield higher percentages
- Low ratios – high efficiency combustion; high ratios – low efficiency combustion
- Interpreted as a measurement of combustion efficiency
 - Simplistic and does not capture the full scope of what is controlling the short term slope calculations

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- Calculation of the change in the mole fractions between two air masses with different characteristics
 - Takes advantage of the fact that CO/CO₂ are co-emitted from the same sources under the same conditions, with distinct ratios
 - Calculated using error adjust bivariate regression
 - Accounts for errors on both the X and Y axes