Observations of Southeast Asian Biomass Burning and Urban Trace Gas Enhancement Ratios: Insights into Regional Air Quality and Aerosol Composition

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Abstract

Southeast Asian biomass burning is a major pollutant source that contributes to poor air quality throughout the region. Thus, understanding these emissions is critical for predicting and mitigating their health impacts. While many studies have reported ground-based and satellite measurements, airborne measurements at a regional scale capable of tying the two together have not been common. The 2019 Cloud, Aerosol and Monsoon Processes Philippines Experiment ($CAMP^2Ex$) field project examined Southeast Asian regional sources and their effects on aerosol/cloud interactions using a combination of airborne, shipboard, and ground-based measurements. These flights sampled a variety of airmass sources over the Philippine, South China, and Sulu seas during both the southwest monsoon and monsoon transition periods. Measurements during CAMP2Ex provide a unique opportunity to investigate how these transported and local emissions affected air quality trends and airmass chemical composition. We present correlated airborne in situ enhancement ratios of CH_4 to CO, using them to identify source regimes of either high urban or biomass burning influence as well as urban regimes with different emission factors. Combined with backtrajectory analysis using HYSPLIT, source regimes were examined for differences in ozone, reactive nitrogen, and aerosol chemical composition. While observed O_3/CO enhancement ratios remain constant for differing urban source regimes, NO_y/CO ratios varied across these regimes. For biomass burning sources, O_3/CO enhancement ratios are observed to be lower than previously reported by measurements in the region.

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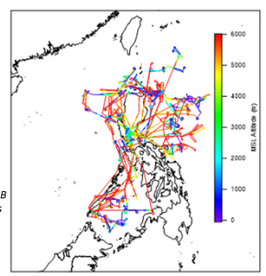
Overview

- Enhancement ratios of CH_4:CO used to apportion biomass burning and urban sources
- HYSPLIT backtrajectory analysis consistent with resulting regime assignment
- Organic aerosol dominate average biomass burning aerosol composition, while sulfates form the plurality of urban emissions
- Enhancement ratios of O_3:CO highly correlated in biomass burning and urban regimes respectively, though with different values

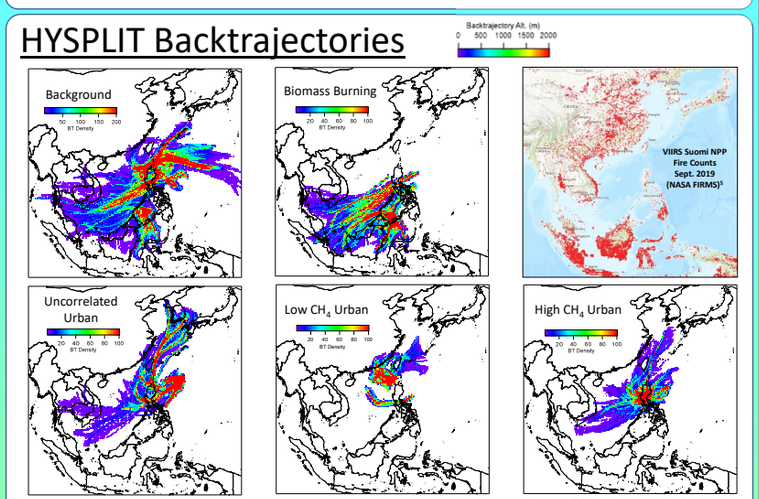
CAMP²Ex Flight Campaign

- Joint NASA/MO/NRL project: Aug-Oct 2019
- Measurements: NASA P-3B aircraft, SPEC Learjet
- Major science question: How do contrasting airmass composition and sources, such as biomass burning (BB) or urban, affect:
  - Aerosol properties
  - Air quality
  - Cloud nucleation & precipitation



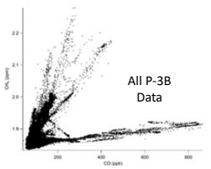
All NASA P-3B flight tracks near the Philippines during CAMP²Ex

HYSPLIT Backtrajectories



- 48 h BT along flight track[6,7]
  - 1 min intervals
  - GFS 0.25° meteorology
  - Only shown < 2 km
- Background flagged air most recently influenced by air over the Philippine and South China Seas
- Biomass burning flagged air influenced exclusively from SE Asia, primarily Borneo, Sumatra, and Sulawesi
- Low CH_4 flagged air influenced by mainland China, while high CH_4 flagged air influenced mostly by local Pilipino emissions
- Uncorrelated urban flagged air influenced predominantly by longer range transport from SE Asia, Korea, & Japan

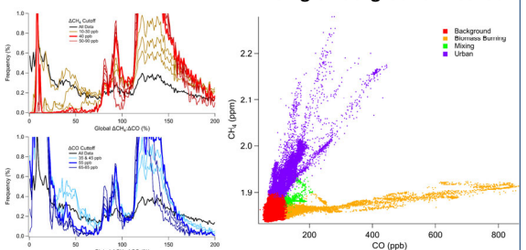
Chemical Influence Apportionment



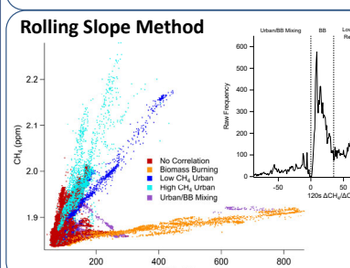
- Enhancement ratios (ER) of CH_4 and CO used to apportion different airmass source influences
  - Partitioned strongly between reported biomass burning[1,2] and urban[3] emission ratios
- Two methods used to separate regimes

Single Background Method

- Single concentration for each species chosen as background lower limit
- Background upper limit chosen by finding minimum in slope distribution at different ER cutoffs (left panels)
- Regime in middle assigned as mixing due to presence of mixing lines

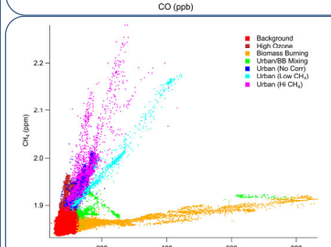


Rolling Slope Method



- ER determined by slope of CH_4:CO fit of 120 s rolling window[4]
- Slopes filtered for only those with strong correlations ($r^2 > 0.5$)
- Minima in distribution of slope distribution identified different regimes (right panel)
  - Negative slopes implied mixing regime
  - Urban regime separated into two regimes, one with lower CH_4:CO ER (low CH_4) and the other with higher CH_4:CO ER (high CH_4)

Final Combined Flag



- Final flag merges regimes from both methods
- Includes "high ozone" regime: evidence of stratospheric influence
- Isolates data within 1 km of takeoff/landing (not shown due to scale)

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NOAA ARL/READY
James Geiger, Mario Rana

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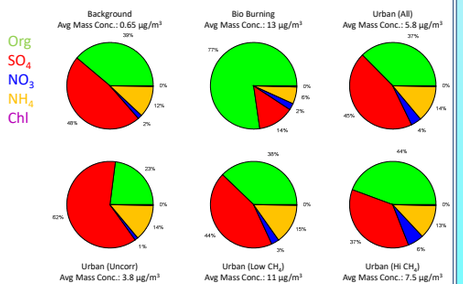
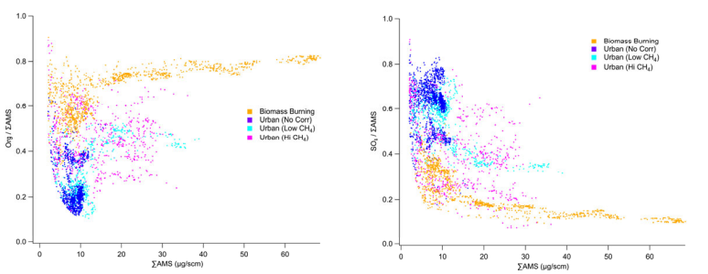
Aerosol Chemical Composition

Relative Mass Contributions by Regime

- Average relative composition from NASA LaRC Aerosol Mass Spectrometer
- Biomass burning apportioned airmasses dominated by organic aerosol contributions
- Urban regimes exhibited higher average sulfate contributions, with the uncorrelated regime exhibiting the highest sulfate proportion



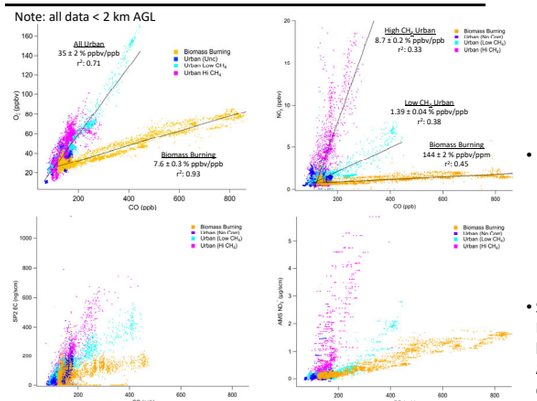
Contributions as Function of Total Mass



- Bio burning and low CH_4 regimes each approach narrow mass contribution range
- Larger spread at high aerosol mass implies higher variety of sources in high CH_4 regime

Trace Gas Enhancement Ratios

Note: all data < 2 km AGL



- Distinct O_3 and CO correlated relationships between Urban and BB regimes
  - Persistent correlation in BB regime despite different relative airmass ages
- NO_y weakly dependent on CO in correlated urban regimes
  - High CH_4 regime clearly exhibits much higher NO_y enhancements compared to Low CH_4 regime
- Similar separation as with NO_y:CO by regime seen in black carbon (BC):CO and AMS nitrate (NO_3^-):CO enhancements