Anthropogenic emissions of highly reactive volatile organic compounds (HRVOCs) inferred from oversampling of OMI HCHO columns

OMI HCHO 2006 JJA average

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Relating HCHO columns to HRVOC emissions

\[ \text{In absence of horizontal wind, mass balance for HCHO column } \Omega_{\text{HCHO}}: \]

\[ \Omega_{\text{HCHO}} = \sum_i y_i E_i \]

but wind smears this relationship
Oversampling approach to detect point/urban sources

- **Oversampling**: temporal averaging of the satellite data on a spatial grid finer than the pixel resolution of the instrument.
- Takes advantage of the spatial offset and changing geometry of the satellite pixels from day to day.
- **Trades** temporal for spatial resolution.
- Achieves higher signal-to-noise ratio.

Optimize smoothing radius:
- Too fine (12 km): Increase noise.
- Too coarse (36 km): Lose spatial features.

Smoothing Radius

A satellite pixel: \(24\times13\text{km}^2\)

2005-2008 MJJAS
26028 pixels in a 1°×1° box
Results: Oversampling of OMI HCHO pixels

Oversampling approach enables detection of anthropogenic HRVOCs from urban/industrial sources and oil/gas operations.
Deriving the HCHO source in the Houston plume

Integration of HCHO columns over plume:

\[ S = \frac{1}{\tau_{\text{HCHO}}} \int \left( \Omega - \Omega_0 \right) dA \]

HCHO VCD

HCHO from long-lived and biogenic VOCs

HCHO Life time

Anthropogenic Enhancement

Regional Background

Coastline

Wind

Houston

OMI HCHO column (10^{15} \text{ molecules cm}^{-2})

Downwind distance (km)
Inference of AHRVOC emissions from the HCHO columns

\[ S = \frac{1}{\tau_{\text{HCHO}}} \iiint (\Omega - \Omega_0) \, dA \]

HCHO lifetime: 1.6±0.5 h

\[ S: 250\pm140 \text{ kmol HCHO h}^{-1} \]

Bottom-up estimate:
\[ 240\pm90 \text{ kmol HCHO h}^{-1} \text{ [Parrish et al., 2012]} \]

Total AHRVOC emission

\[ E = \frac{S}{\sum_i f_i Y_i} \]

Fraction of the total emission

HCHO yield

EPA NEI05: emissions and HCHO production (kmol h\(^{-1}\))

AHRVOC emissions in the Houston plume area are underestimated by a factor of 4.8±2.7 in EPA NEI05 inventory for 2005–2008.
Indistinguishable HCHO enhancements in winter at Houston

- HCHO enhancements at Houston are indistinguishable during winter even by oversampling, due to smearing resulting from low OH and high wind speed.
- This suggests that anthropogenic HCHO is mainly secondary rather than primary.
Oversampling of OMI HCHO pixels in China, 2005-2008

Aoxing Zhang and Lei Zhu
**Take home messages**

- Oversampling of OMI HCHO columns solves the long-standing problem of detecting and quantifying US AHRVOC emissions from space.
- AHRVOC emissions for Houston are $4.8 \pm 2.7$ times higher than that in EPA inventory.
- Due to low OH and high wind speed, OMI HCHO enhancements in winter are indistinguishable at Houston, which suggests that anthropogenic HCHO is mainly secondary.

**Future work**

- Improving the oversampling technique: e.g., using Gaussian or inverse distance weights for spatial smoothing
- Detecting long-term trends of HCHO in urban/industrial areas and oil/gas fields
- Looking at HCHO over China
- Linking HCHO with other information, e.g., wind speed, wind direction, or glyoxal columns