Determination of Isoprene Emissions from Aircraft Measurements During 4 Campaigns and Comparison with Emission Inventories

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Compare measurements versus inventories using:
1. Mixed-boundary layer method
2. Flexpart model
Inventories used: BEIS3.12 and 3.13, MEGAN and Wiedinmyer et al. for Texas
Top-Down Evaluation of Biogenic VOC Inventories

Different methods have been used previously:

1. Eddy-covariance flux measurements
e.g. Guenther and Hills [JGR 1998]
   very accurate, but only 1 location

2. Using satellite-derived formaldehyde
e.g. Palmer et al. [JGR 2006]
   large scale, but indirect

3. Regional chemistry models vs. measurements
e.g. Mueller et al. [ACP 2008]
   emissions, meteorology and chemistry all have to be correct

Here: use airborne measurements to estimate isoprene emissions at the aircraft location and compare with inventories
NOAA Aircraft Measurements of Biogenic VOCs in the U.S.

**VOC measurements:**
- Canister sampling
- Airborne GC
- Proton-Transfer Reaction Mass Spectrometry
Approach 1: Mixed Boundary Layer Method

1. Estimate Emissions from Measurements
   - assume well-mixed PBL
   - PBL height from aircraft data
   - estimate emissions
   - estimate OH $\Rightarrow$ VOC lifetime

2. Calculate Emissions from Inventory
   - Temperature and PAR from aircraft data

3. Compare Measurements to Inventories

Inventories used in this work:
- BEIS3.12
- BEIS3.13
- WM2001 [Wiedinmyer, AE 2001] (TX only)
- MEGAN [Guenther, ACP 2006]
Step 1: Estimate Emissions from Measurements

isoprene emission - $F_e = \text{measured concentration} \times BL_{\text{height}} \times OH \times k_{OH}$

- $F_e = \text{entrainment flux}$
- $BL_{\text{height}}$ from aircraft data
- $OH$ from parameterization using $j_{O_3}$, $j_{NO2}$, and $NO_2$
  
  [Ehhalt, JGR 2000]

- Uncertainty: -50%, +100%
Step 2: Calculate Emissions from Inventory - BEIS

isoprene emission = base emission × \( c_t \times c_l \)

- \( c_t \) = temperature factor
  temperature from aircraft

- \( c_l \) = light factor
  PAR from aircraft using leaf-area index (LAI)
Step 2: Calculate Emissions from Inventory - MEGAN

isoprene emission = base emission ×

\[ \gamma_t \times \gamma_l \times \gamma_{LAI} \times \gamma_{age} \]

- \( \gamma_t \) = temperature factor from aircraft data
- \( \gamma_l \) = light factor from aircraft data
- \( \gamma_{LAI} \) = leaf-area index factor
- \( \gamma_{age} \) = leaf-age factor from ECMWF past 15-day weather
Differences Between Inventories

Actual emissions along flight tracks:

- BEIS 3.13 = 0.67 \times BEIS 3.12
different light parameterization

- MEGAN = 1.79 \times BEIS 3.12
different base emissions

- WM2001 = 0.72 \times BEIS 3.12
Step 3: Compare Measurements to Inventories

- Overall agreement within factor of ~2
- MEGAN higher than most measurements; BEIS 3.13 lower
- Texas: higher emissions in 2006 than in 2000
Approach 2: Calculate Isoprene with FLEXPART - BEIS 3.12

FLEXPART
- Lagrangian transport model [Stohl, JGR 2003]:
- ECMWF meteorology
- No chemistry: remove isoprene after 1 hour of transport

BEIS 3.12
- 0.15° x 0.15° resolution
- Temperature and light from ECMWF
Approach 2: Calculate Isoprene with FLEXPART - BEIS 3.12

Example: September 16, 2006, over NE Texas

- Model releases 40,000 particle back-trajectories from each measurement location
- Footprint is BL residence time of all particles
- Isoprene concentration = footprint × emissions from BEIS 3.12
- Isoprene removed after 1 hour of transport
FLEXPART - BEIS 3.12 vs. Measured Isoprene

Example: September 16, 2006, over NE Texas

➢ Agreement within factor of ~2
Texas: good agreement
Northeastern U.S.: FLEXPART $\approx 2 \times$ measured data

Slope was 0.98 in previous method
Slope was 1.65 in previous method
Summary

1. Two methods were used to compare airborne measurements of isoprene directly with inventories: overall agreement within factor of ~2 is found in both methods.

2. For all areas: MEGAN > BEIS 3.12 > BEIS 3.13

No time to show:

3. Larger uncertainties for monoterpenes

4. Method allows identification of local differences e.g. discontinuity at U.S.-Canadian border in BEIS TX hotspot between Dallas and Houston
# Acknowledgements

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<th>Name</th>
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