HCOOH distributions from IASI with updated retrieval parameters: comparison with ground-based FTIR measurements and IMAGESv2 model

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Tropospheric formic acid (HCOOH)

- HCOOH is one among the most abundant volatile organic compounds (VOCs) present in the atmosphere.
- With acetic acid it is a major contributor to the acidity of precipitation

• Many sources:
  secondary product from other organic precursors + small direct emissions by vegetation, ants, biomass burning, soils, agriculture, motor vehicles.

• Sinks:
  mainly removed through wet and dry deposition + (lesser extent) oxidation by the OH radical

HCOOH = short-lived species
lifetime is conditioned by the ratio of precipitation: in the boundary layer 2 days (rainy period) → 6 days (the dry season). Global lifetime in the troposphere=3–4 days

Photochemical loss is relatively slow (τ ∼ 25 days), so that any HCOOH formed or vented outside of the boundary layer can be transported for long distances in the free troposphere.
HCOOH: our knowledge is incomplete

Recent studies highlight:

A misrepresentation of emission from tropical and boreal forest in models (Stavrakou et al., Nature 2011)

A possible source of HCOOH over the Arctic Ocean (Jones et al., Atmos. Env 2014).

One or more large missing sources (Millet et al., ACPD 2015) → suggest a gap in our current understanding of hydrocarbon oxidation or the existence of an unknown direct flux
Space missions allow getting global observations of the atmosphere

Their spatial coverage allows observing remote regions which are sparsely studied by field campaigns

Limited vertical sensitivity

Few satellites provide tropospheric HCOOH observations

**Nadir-viewing instruments:** Infrared Atmospheric Sounding Interferometer (IASI) (e.g. Coheur et al., 2009), Tropospheric Emission Spectrometer (TES) (e.g. Cady-Pereira et al., 2014)

**Solar-occultation instrument:** Atmospheric Chemistry Experiment (ACE) (e.g. González Abad, 2009)

**Limb instrument:** Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) → global distribution of HCOOH at 10 km (Grutter et al., 2010).
HCOOH: observations with IASI

**MetOp**: First European meteorological platform in polar orbit launched by EUMETSAT in 2006 (IASI-B launched in 2012)

- Small ground pixel size
- Global coverage twice daily (morning and evening orbits) – 14 revolutions/day
- 4 pixels (12 km at nadir)
- 120 spectra along the swath (±48.3° Scan → 2400 km), each 50 km along the trace

Spectra given in radiance or brightness temperature → signal from HCOOH expressed in ΔBT

Clerbaux et al. (2009)

Coheur et al. (2009)
Objective = find an accurate and fast technique to convert the ΔBT to total columns, avoiding a large computing time → necessary to analyze 7 years of data

First global distribution by IASI (Razavi et al., ACP 2011)

Detection of extreme events: forest fires in Russia on 2010 (R’Honi et al., ACP 2013)

Retrieval relevant for huge amount of HCOOH
MEGAN-MACC HCOOH emissions for the period between 2008 and 2010 on a 0.5°×0.5° grid. (Sindelarova, ACP 2014)

FTIR sites location

<table>
<thead>
<tr>
<th>Region</th>
<th>Localization</th>
<th>Number of retrieved spectra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa N</td>
<td>6-7°N 18-22°E</td>
<td>265</td>
</tr>
<tr>
<td>Africa S</td>
<td>12-14°S 20-24°E</td>
<td>788</td>
</tr>
<tr>
<td>Amazonia</td>
<td>6-10°S 43-45°W</td>
<td>682</td>
</tr>
<tr>
<td>Atlantic</td>
<td>22-24°N 42-45°W</td>
<td>675</td>
</tr>
<tr>
<td>Australia</td>
<td>14-15°S 131-133°E</td>
<td>218</td>
</tr>
<tr>
<td>Pacific</td>
<td>20-22°S 140-142°E</td>
<td>472</td>
</tr>
<tr>
<td>Russia</td>
<td>50-54°N 60-62°E</td>
<td>538</td>
</tr>
</tbody>
</table>

Data retrieved over 7 regions → emission sources, remote area, areas influenced by long-range transport + land and sea scenes

Seasonal variation is taken account: 5 first days of each month on 2009 are retrieved
Parameters:
• 1095-1114 cm\(^{-1}\)
• Cloud fraction < 2%
• Same a priori than Razavi et al. (2011)
• Thermal contrast > 0 K (\(T_{\text{surf}} - T_{\text{atm 1st layer}}\)) \((\text{Razavi et al. used } TC > 5K)\)
• day-time and night-time data used

Good correlation between retrieved columns and \(\Delta BT\)

But conversion is dependent on the TC
Establishment of a new dataset

Reduction of the thermal contrast dependence:
Mean over 7 regions

![Graphs showing correlation between ΔBT and TC and correlation between retrieved columns and corrected ΔBT (TC)](image)

**Conversion using both relationships:**
Column \( = 1.742 \times (\Delta BT - TC \times 0.0361 - 0.1969) + 0.646 \)
Error estimation

3 terms:
1) the instrumental error
2) the error caused by the conversion between the $\Delta BT$ and the total column
3) the error from the retrievals.

Total error by forward simulation (>3000 spectra):
- Gaussian distributed random noise ($\sigma = 0.15$K) added to the BT channels
- the conversion formula is applied on the calculated $\Delta BT$.

$\overline{RD} = 26\%$
$|\overline{RD}| = 74\%$
Std RD = 88\%

→ large errors
Comparison with FTIR (± 0.5°, daily mean)

Simple altitude correction of total columns: \( C' = C \times \exp(\text{Alt}/7.4) \)

**Jungfraujoch**
- (3.6 km alt)
- \( R = 0.15 \)
- Bias = 1.19 x 10^{16} molec/cm²

**Saint Denis**
- (La Réunion – 0.26 km alt)
- \( R = 0.74 \)
- Bias = 0.30 x 10^{16} molec/cm²

**Wollongong**
- (0 km alt)
- \( R = 0.56 \)
- Bias = 0.01 x 10^{16} molec/cm²

**Maido**
- (La Réunion – 2.5 km alt)
- \( R = 0.48 \)
- Bias = 0.32 x 10^{16} molec/cm²

IAMSI

FTIR
Seasonal Variation (global distribution)

IASI (gridded IMAGESv2 = 2°x2.5°)

2008-2013

DJF

MAM

JJA

SON
Conclusions

• Global overview of HCOOH
• 7 years of data to analyze
• Detection hotspots (MiddleEast US, Asia...) & seasonal cycle

• No averaging kernels → difficulties to compare IASI total columns to FTIR and simulations

• Challenge in the interpretation of the data → misrepresentation of sources
Extra slides
TES
Cady-Pereira et al. AMT 2014

IASI
Detection of extreme events: fires over Russia

0.2°×0.2° 27 July – 27 August 2010 over Russia

HCOOH total column

CO total column
Detection of extreme events: fires over Russia

0.2°×0.2° 27 July – 27 August 2010 over Russia

HCOOH total column

MODIS hotspot