Contribution to the study of tropical biomass burnings: Observation of carbon monoxide emitted by fires with IASI

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Biomass burnings and spatial observation

General Characteristics of fires:

Annual emissions = 2,0 GtC*
Tropics = 80%* emissions
Africa = 52 %* ; South America = 15 %*
90% CO$_2$, 9% CO, <1% CH$_4$, and other trace gases

* GFEDv3 averaged over 1997-2009, van der Werf et al., 2010,

- Observations of mid-tropospheric CO$_2$ and CH$_4$ are available from space-borne instruments, in particular from Thermal IR sounders (e.g. with TOVS (Chédin et al., 2003), AIRS (Crevoisier et al., 2004) and IASI (Crevoisier et al., 2009a/b))

- However, the fire signature on CO$_2$ and CH$_4$ is weak because of the high background level of CO$_2$ and the weak amount of CH$_4$ emitted by fires

Therefore, we focus on biomass burning and CO in Southern Africa
Contribution of IASI to the study of biomass burnings

Sensitivities of IASI channels to atmospheric and surface perturbations
(from LMD 4A radiative transfer model, based on the GEISA spectroscopic database and using the TIGR atmospheric dataset)

Mean TIGR sensitivity in the tropics

\[
\begin{align*}
\text{CO}_2 & (1\%) \quad \text{CH}_4 & (20\%) \quad T & (1\text{K}) \quad \text{H}_2\text{O} & (20\%) \quad \text{O}_3 & (10\%) \quad \text{CO} & (10\%) \quad T_{surf} & (1 \text{K}) \quad \text{Emi} & (5\%)
\end{align*}
\]

Simultaneous observations:
\[
\text{CO}_2, \text{CH}_4, \text{CO}
\]

- Spectral resolution 0.5 cm\(^{-1}\) - 8461 channels

\[\text{Scott et Chédin, 1981} \quad \text{Jacquinet-Husson et al., 2008} \quad \text{Chédin et al., 1984}\]

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<table>
<thead>
<tr>
<th>Species</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>1%</td>
</tr>
<tr>
<td>CH₄</td>
<td>20%</td>
</tr>
<tr>
<td>T</td>
<td>1 K</td>
</tr>
<tr>
<td>H₂O</td>
<td>20%</td>
</tr>
<tr>
<td>O₃</td>
<td>10%</td>
</tr>
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- CO₂, CH₄, CO

- Spectral resolution 0.5 cm⁻¹
- 8461 channels

Scott et Chédin, 1981
http://www.noveltis.fr/4AOP/

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Retrieval method – Sélection of CO channels

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Mean TIGR sensibility in the tropics

Objective: to find couples of channels which have the same sensitivities to every atmospheric and surface parameter, except for CO.

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Mean TIGR sensibility in the tropics

CO (10%)  T (1K)  H₂O (20%)  Tsurf (1 K)  Emi (5%)

Vibrations of the BT (K)

Wave number (cm⁻¹)

CO Jacobian

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Chédin et al., 1984
Taking the difference between the 2 channels cancels the aerosols effect.

- INSO, SOOT and WASO aerosols characteristics supplied by the OPAC database
- 0.05 AOD

Sensitivities of IASI channels to smoke aerosols
(from LMD 4A radiative transfer model coupled to DISORT, based on the GEISA spectroscopic database and using the TIGR atmospheric dataset)
Description of the retrieval method

- ERA-INTERIM Reanalyses: T, H$_2$O and O$_3$ profiles
- Carbon Tracker*: CO$_2$ profiles

Channels selection

- Colocalisation with IASI and interpolation on the 40 4A pressure levels

Estimation of Ts with the 2501.75 cm$^{-1}$ channel

4A simulations of BT and Jacobians

IASI Observations

- Clear sky detection

From Ether Centre, via Eumetcast

$\Delta$BT = (BT$^{4A}$ - BT$^{IASI}$)$_{\text{chan1}}$ - (BT$^{4A}$ - BT$^{IASI}$)$_{\text{chan2}}$

$\Delta$qCO = $\Delta$BT (K) / (Sensitivity$_{\text{chan1}}$ - Sensitivity$_{\text{chan2}}$) (K/ppbv)

Method based on 3 differences of 2 IASI channels:

- Channel 1: sensitive to CO
- Channel 2: not sensitive to CO

*Wouters et al., 2007

Péquignot, private comm.
Results – Monthly means of IASI CO (2008)

Day

Night

Jan

Feb

Mar

Apr

May

Jun

Day

Night

Jul

Aug

Sep

Oct

Nov

Dec

Precision ~ 3%
Study of the night (19h30) minus day (7h30) difference of retrieved CO$_2$ (NOAA-10) (averaged over June-July-August 1987-1990)

**Daily Tropospheric Excess**

Diurnal cycle of fires

Diurnal cycle of fires in the surface and equator crosstime of NOAA-10 and IASI

Convection of fires emissions in the troposphere

Simulation of CO$_2$ fire plumes emissions

Freitas et al., 2007, find similar patterns

Giglio, 2006
Monthly means of daily IASI CO vs. FRP

Day-night CO

Fire Radiative Power

Day-night CO

Fire Radiative Power

FRP MODIS: Justice et al., 2002
Spatio-temporal evolution averaged over SAf

Monthly variations of fire products
(January to December 2008, averaged over Southern Africa)

FRP MODIS: Justice et al., 2002 ; BA MODIS: Roy et al., 2008 ; GFEDv3: van der Werf et al., 2010
Monthly variations of fire products and CO
(January to December 2008, averaged over Southern Africa)

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Spatio-temporal evolution averaged over 10 areas

Areas in South Africa corresponding to different types of vegetation (Chédin et al., 2008)
Spatio-temporal evolution averaged over 10 areas

Monthly variations of fire products and CO
(January to December 2008, averaged over Southern Africa)
We have used the IASI/MetOp observations to retrieve tropospheric CO mixing ratios and to study the link between CO and biomass burnings.

These results have highlighted:
- the diurnal cycle of tropospheric CO over Southern Africa
- a temporal and spatial variation of this signal, in agreement with fire activity
- a lag of the seasonal cycle for some areas that need to be explained

Perspectives of this work:
- extension to all the IASI period and to the tropics
- study of the correlations between CO$_2$, CO and CH$_4$
- study of the vertical transport of gases emitted by fires
Annex
Daily Variations of CO

More CO seen by IASI by day (09:30) than by night (21:30)

CO is mainly emitted in the **smoldering phase** of combustion:

- low-temperature process
- burns the organic layer, after the aboveground biomass was consumed in the daytime releasing mostly CO$_2$
- conditions of higher moisture

CO is emitted mostly at night and trapped into the boundary layer until the next morning, and then uplifted by convection

Case of a wildland biomass fire in Alaska ([Ferguson et al., 2003](#))

10 July: ignition

11 July at 00:00 ADT

12 July at 00:00 ADT