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Detection of extreme events from IASI observations

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Introduction

- The 3 IASI instruments on-board the Metop satellites have been sounding the atmospheric composition since 2006 allowing the monitoring of atmospheric chemistry (Clerbaux, et al 2009) and the detection of exceptional events such as fires (Coheur et al., 2009; R'Honi et al., 2013), volcanic eruptions (Clarisse et al., 2008) or pollution events (Boynard et al, 2014).
- The early detection of extreme events is key to take appropriate decisions regarding protection of inhabitants and the environment.
- With IASI providing global observations twice a day in near real time, a new way for the systematic and continuous detection of exceptional atmospheric events to support operational decisions is possible.

Objectives

- Using and improving a method for the detection and characterization of extreme events, which relies on the principal component analysis method (Atkinson, N. C., 2010, 2011; Chefdeville S., 2010).
- Creating a record of extreme events (volcanic eruption and fires) based on IASI data.
- Characterizing and classifying fire, volcanic eruption and pollution events.

Method

The Principal Component method

- The reference database is generated using nearly 120 000 spectra randomly selected in 2013 over the entire globe.
- From the reference database, eigenvectors are created to statistically depict the atmospheric variability during a full year, around different conditions of acquisition over the entire globe.
- By projecting raw apodized spectra (y) on the eigenvectors, reconstructed spectra \tilde{y} are obtained, which are supposed to contain only information on the standard atmospheric variability, except for anomalous events.
- The residual normalized by the IASI noise (N) is calculated as follows: $r = N^{-1}(y - \tilde{y})$.

Spectral bands (cm ⁻¹)	Peaks (Spectroscopic Database)	Molecule ID
667.250 - 667.750	667.5 cm ⁻¹ (Q-branch CO ₂)	CO ₂
711.500 - 713.500	713 cm ⁻¹ (Q-branch of HCN v ₂)	HCN
729.250 - 730.000	729.25 cm ⁻¹ (C ₂ H ₂ Q-branch v ₂)	C ₂ H ₂
763.000 - 763.750	763 cm ⁻¹ (v ₂ HNO ₂)	HNO ₂
821.750 - 822.250	822 cm ⁻¹ (C ₂ H ₂ Q-branch v ₂)	C ₂ H ₂
853.500 - 854.250	854 cm ⁻¹ (NH ₃ Q-branch)	NH ₃
867.750 - 868.250	868 cm ⁻¹ (NH ₃ Q-branch)	NH ₃
878.500 - 880.000	879 cm ⁻¹ (v ₂ HNO ₂)	HNO ₂
887.250 - 888.250	888 cm ⁻¹ (NH ₃ Q-branch)	NH ₃
891.750 - 892.250	892 cm ⁻¹ (NH ₃ Q-branch)	NH ₃
895.500 - 896.750	896 cm ⁻¹ (v ₂ HNO ₂)	HNO ₂
908.000 - 909.000	908.3 cm ⁻¹ (NH ₃ Q-branch)	NH ₃
931.750 - 933.750	930 cm ⁻¹ (transition NH ₃ Q-branch)	NH ₃
949.000 - 950.500	949 cm ⁻¹ (v ₂ band vibration liaison CH ₄)	C ₂ H ₂
966.000 - 968.000	967 cm ⁻¹ (transition NH ₃ Q-branch)	NH ₃
991.750 - 993.500	992.8 cm ⁻¹ (NH ₃ Q-branch)	NH ₃
1007.750 - 1008.250	1008 cm ⁻¹ (NH ₃ Q-branch)	NH ₃
1034.000 - 1034.750	1034 cm ⁻¹ (CH ₃ OH Q-branch)	CH ₃ OH
1046.250 - 1047.250	1047 cm ⁻¹ (NH ₃ Q-branch)	NH ₃
1065.750 - 1066.250	1066 cm ⁻¹ (NH ₃ Q-branch)	NH ₃
1075.750 - 1076.250	1076 cm ⁻¹ (NH ₃ Q-branch)	NH ₃
1084.500 - 1085.750	1085 cm ⁻¹ (NH ₃ Q-branch)	NH ₃
1103.000 - 1104.250	1104 cm ⁻¹ (NH ₃ Q-branch)	NH ₃
1104.500 - 1105.750	1105 cm ⁻¹ (v ₂ band Q-branch)	HCOOH
1180.500 - 1184.750	1184 cm ⁻¹ (v ₂ band Q-branch)	CH ₃ COOH
1121.500 - 1122.750	1122 cm ⁻¹ (NH ₃ Q-branch)	NH ₃
1325.750 - 1326.250	1326 cm ⁻¹ (v ₂ HNO ₂)	HNO ₂
1344.500 - 1346.500	1345 cm ⁻¹ (SO ₂ v ₂ band)	SO ₂
1370.500 - 1372.000	1371 cm ⁻¹ (estimate absorption in the SO ₂ v ₂ band)	SO ₂
1375.750 - 1377.000	1376 cm ⁻¹ (absorption in the SO ₂ v ₂ band)	SO ₂
1710.750 - 1711.500	1711 cm ⁻¹ (Q branch HNO ₂)	HNO ₂
1776.750 - 1777.250	1777 cm ⁻¹ (HCOOH v ₂ band)	HCOOH
2032.500 - 2087.000	2050.2 - 2069.65 cm ⁻¹ (v ₂ OCS branch)	OCS
2111.000 - 2112.250	2111.50 cm ⁻¹ (P-branch CO)	CO
2123.000 - 2124.250	2123.75 cm ⁻¹ (P-branch CO)	CO
2130.000 - 2132.250	2131.75 cm ⁻¹ (P-branch CO)	CO
2157.750 - 2158.725	2158.00 cm ⁻¹ (R-branch CO)	CO
2164.750 - 2166.000	2165.75 cm ⁻¹ (R-branch CO)	CO
Not defined	Unknown	UNKNOWN

Table.1 : Definition of molecule indicators using known absorption peaks for the characterisation of PCA detections.

The MIN_MAX_RESIDUALS method

- For a given granule, the extreme values of the residuals are saved for each IASI channel for the entire spectral domain (645cm⁻¹ to 2760cm⁻¹) → we obtain an array called « MIN_MAX_RESIDUAL » (Fig.1).
- By analyzing the signal in each IASI channel of the MIN_MAX_RESIDUALS, we compare the strongest peaks to pre-defined micro-windows where specific molecular signatures are expected (Table.1).
- The method is applied on a granule basis to allow the detection in real time.

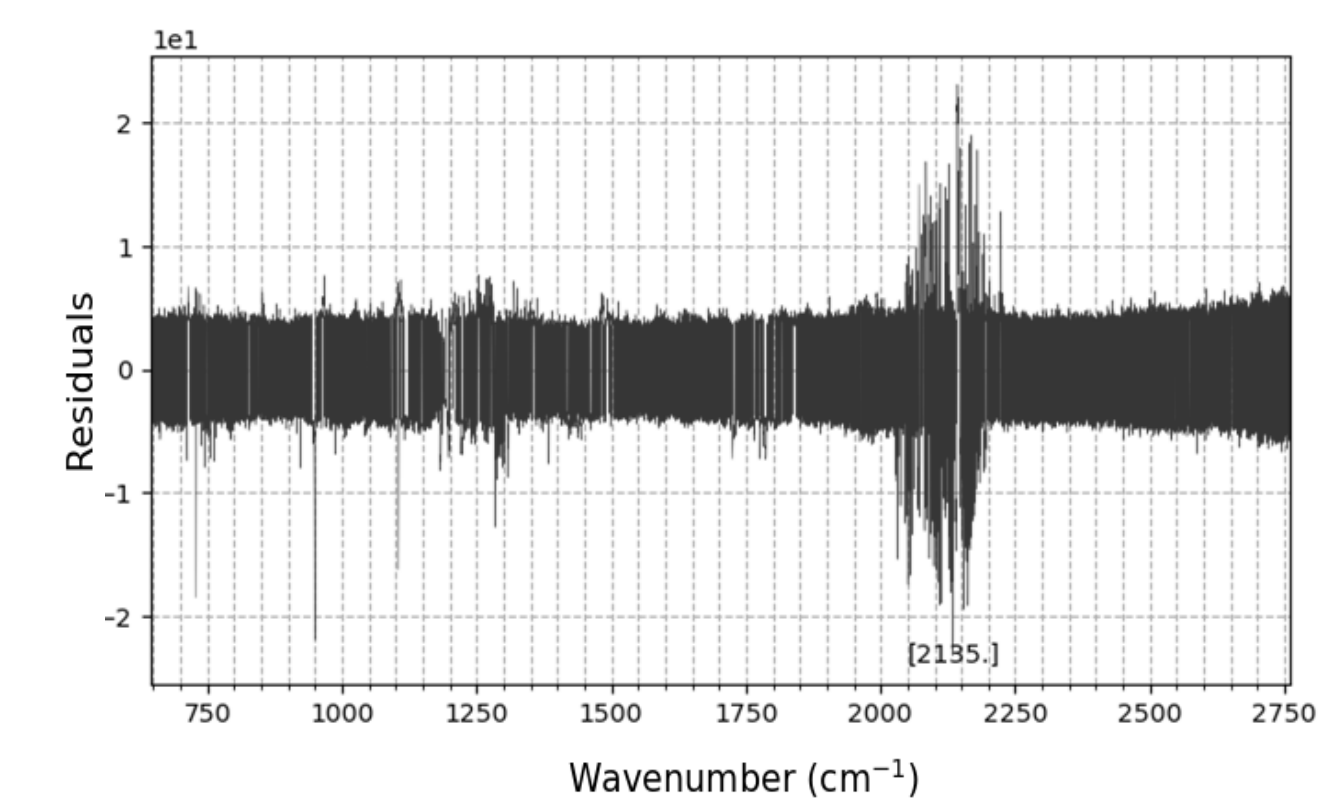


Fig.1 : Example of strongest features observed in Australian fires residuals during the day (2020/01/01) from the MIN_MAX_RESIDUALS.

Results: analysis of the year 2020

Volcanic eruption events

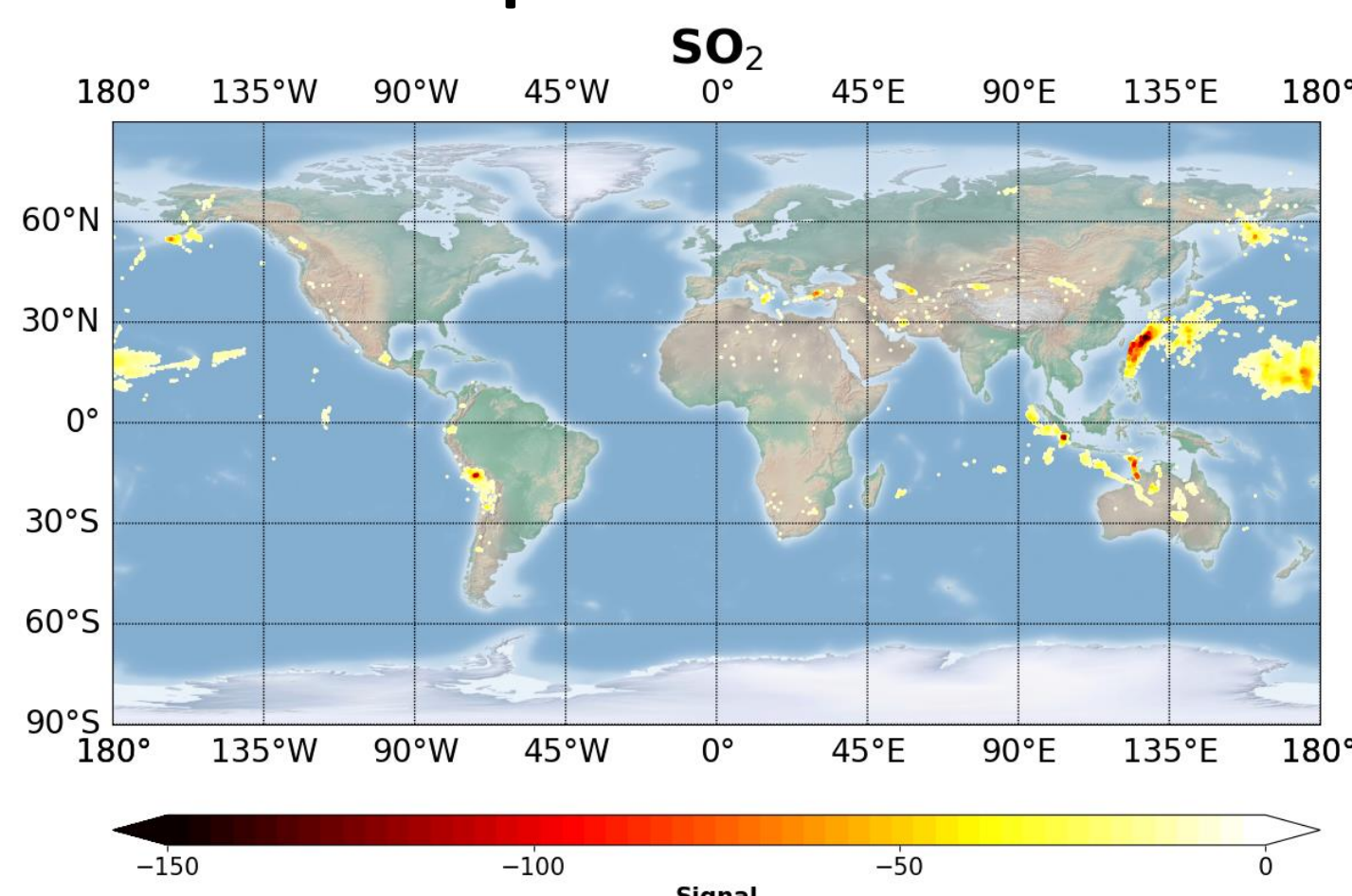


Fig.3 : Spatial distribution of PCA detection pixels for indicators SO₂ (left) and for indicators HNO₃ (right) for the year 2020.

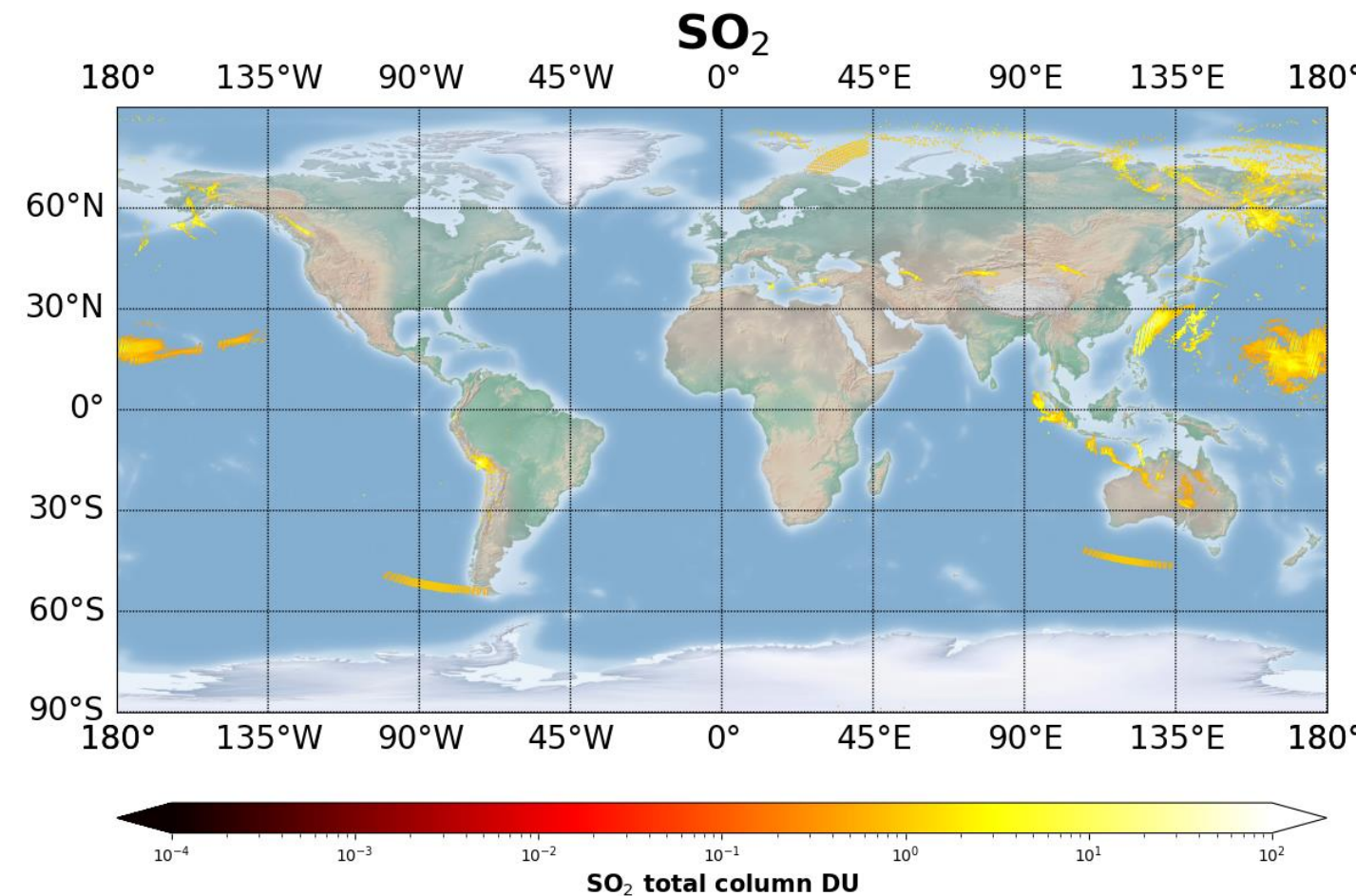


Fig.4 : Spatial distribution of IASI L2 SO₂ total column for the year 2020.

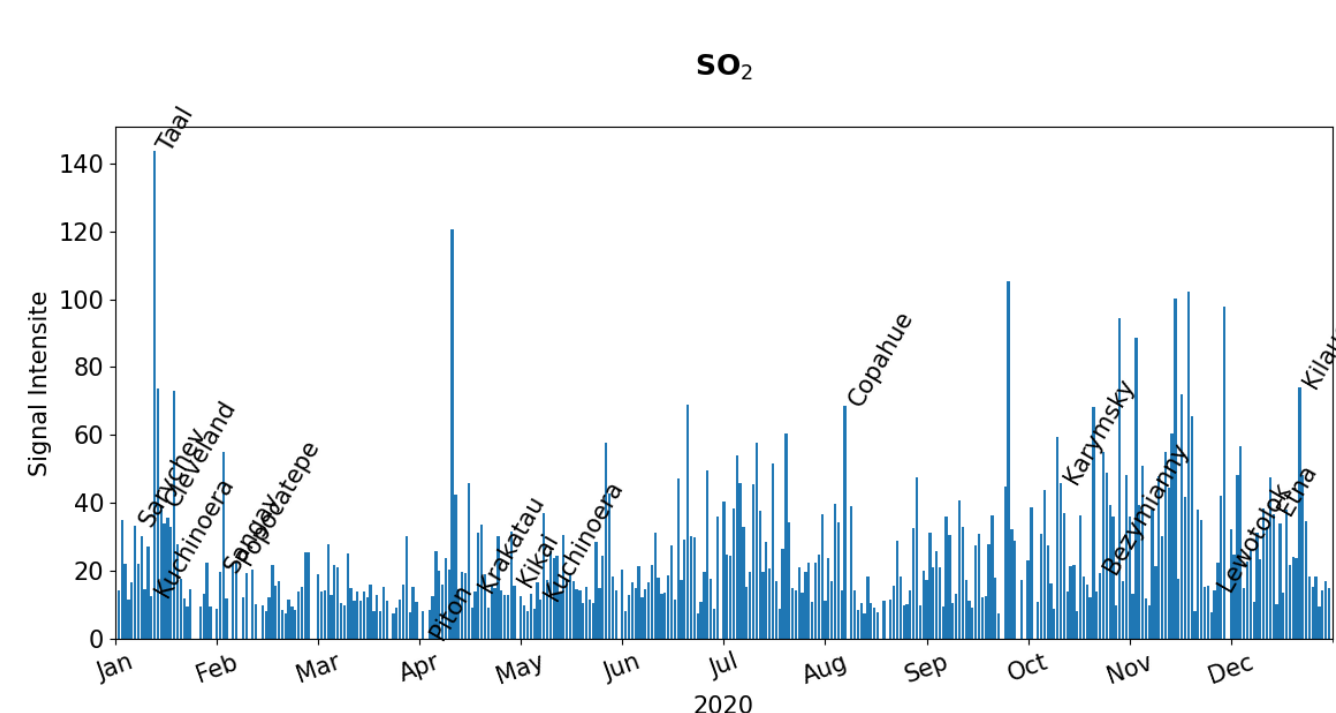


Fig.6 : Maximum absolute intensity of PCA signal for the 2020 year with referenced eruptions in black.

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Fire events

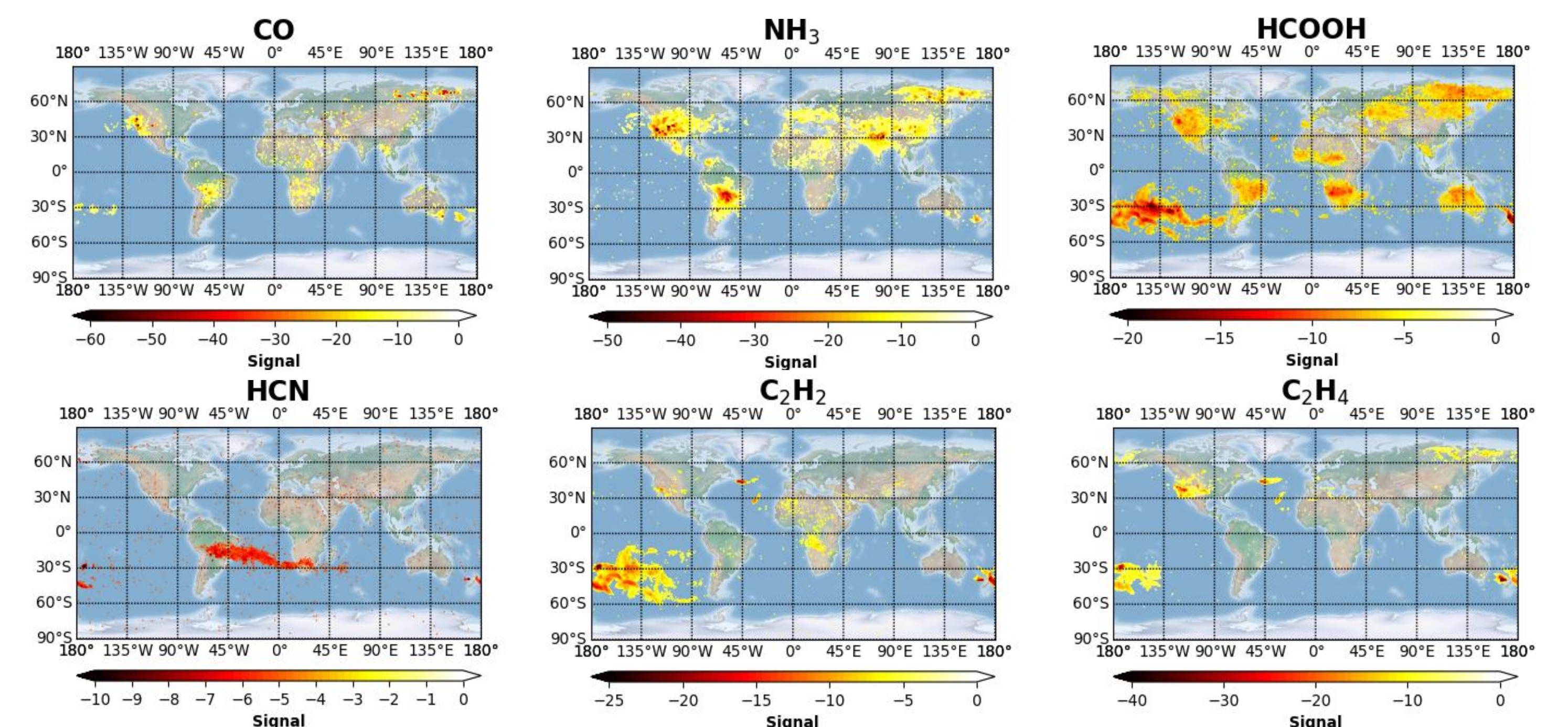


Fig.7 : Spatial distribution of PCA detection pixels for indicators CO, NH₃, HCOOH, HCN, C₂H₂ and C₂H₄ for the year 2020.

- The PCA method is able to detect volcanic eruptions with the indicators for HNO₃ and SO₂ (Fig. 3).
- The PCA method detect more volcanic eruptions than the L2 data (Fig. 4).
- An excellent agreement is found between SO₂ PCA and L2 data. This allow potentially a fast quantification of this molecule (Fig. 5).
- Record of volcanic eruption events for 2020 with PCA (Fig. 6).

- Indicators for CO, NH₃, HCOOH, HCN, C₂H₂ and C₂H₄ are used for the detection of fires and show different molecular species emitted by fires in Australia, Siberia, Brazil, Africa and California (Fig.7).

- The method allows to detect extreme events, especially in case of the presence of large concentrations.
- Multiple indicators can detect same events, allowing a characterization and a classification of an extreme event.

Future work

- Extending the record of volcanic eruption events based on IASI L1 data for the entire IASI period.
- Validating the method for fire events (comparison with Level 2 data).
- Characterizing and classifying the events.

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