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Use and impact of PCA-reconstructed radiances for atmospheric composition applications

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Introduction

The IASI Level 1C radiances have been exploited extensively in the last decade for applications in air quality, climate, tropospheric and stratospheric chemistry. They allow to retrieve an impressive series of atmospheric trace gases, including several that display very small spectral signatures or others that appear only around localized pollution sources or in volcanic and fire plumes.

Despite the success of IASI mission which delivers continuous and long-term datasets, the accumulation of data has generated huge data volume, which will be even larger with future hyperspectral sounding missions (IASI-NG, IRS-MTG). The significant gain of data volume that can be obtained with principal component (PC) based approaches is one of the main motivations for this research. The other advantage is that it leads to a reduction of noise in the reconstructed radiances (RR).

However, a concern with the distribution of PCA reconstructed spectra is the potential loss of small spectral signatures, particular for applications in atmospheric chemistry and climate. This poster reports the results from a comprehensive evaluation of the Eumetsat IASI RR spectra. We investigate two different alternative PCA methods:

- the standard PCA approach based on static eigenvectors, also referred to as PC-global
- the PC-hybrid approach which uses a combination of global and local eigenvectors.

The principal goals of this study are:

1. to evaluate how well the IASI Level 1C can be reconstructed from the eigenvectors produced at EUMETSAT, and to document the added value of PC-hybrid over PC-global for rare or extreme situations.
2. to evaluate to what extent the use of reconstructed radiances impacts the retrieval of trace gases, in background or extreme situations.

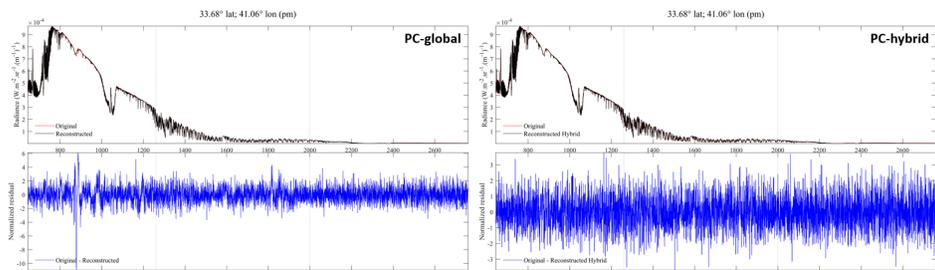
Molecules and scenarios investigated

- O₃, CO, HNO₃ in standard situations
- O₃ profile retrievals and comparison with sondes
- CO retrievals in severe fire conditions
- NH₃ in normal conditions
- SO₂ in volcanic eruptions
- rare features (eg. Dust minerals, emissivity effects)

Only selected results are presented here.

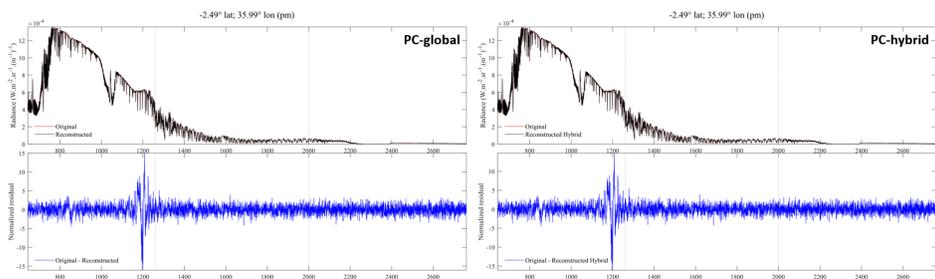
Performance of reconstruction on rare case – at radiance level

Iraq desert (calcite in absorption): 19.02.2009



Original and reconstructed (with PC-global (left) and PC-hybrid (right) approaches) spectra of calcite in absorption over the Iraq desert (33.68°N 41.06°E); and the difference.

Lake Natron (trona, thermonatrite and kogarkoite in absorption): 15.12.2007



Original and reconstructed (with regular (left) and hybrid (right) approach) spectra of trona, thermonatrite and kogarkoite in absorption over the Lake Natron (2.49°S 35.99°E); and the difference.

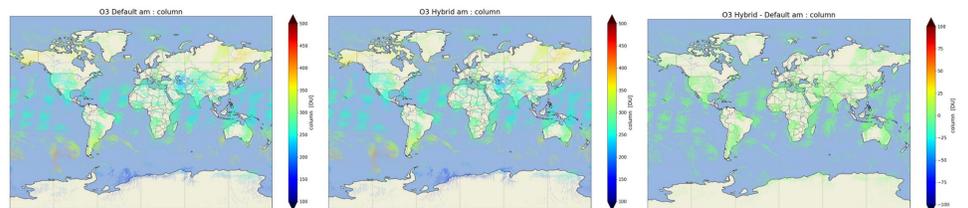
Region	Latitude	Longitude	Date		PC-global	PC-hybrid
Lake Natron	-2.49°	35.99°	2007.12.15	Trona, thermonatrite and kogarkoite	x	x
Iraq desert	33.68°	41.06°	2009.02.19	Calcite in absorption	x	v
Saudi desert	25.24°	47.06°	2007.11.10	Calcite in emission	x	x
Qinghai	33.89°	93.42°	2008.05.03	Dolomite	x	v
Australian fires	am: -28.75° pm: -33.24°	am: -173.71° pm: 178.06°	2020.01.05	Fire tracers: C ₂ H ₂ /CH ₃ OH/C ₂ H ₄ /HCOOH/HCN/PAN/C ₄ H ₆ O/ ...	x	v
Industrial park	39.4°	106.7°	2012.05.02	C ₂ H ₄ /CH ₃ OH/NH ₃ /C ₂ H ₂ hotspot	v	v
China	36°	114°	2010.06.14	Ammonium sulfate	v	v
Ammonia	50.37° 56.53°	64.12° 45.90°	2012.08.10 2010.08.15	NH ₃ absorption NH ₃ emission	x v	x v
Antarctica	-80°	90°	2010.07.15		v	v

Performance of reconstruction on rare cases. (v = well reconstructed, x = not well reconstructed)

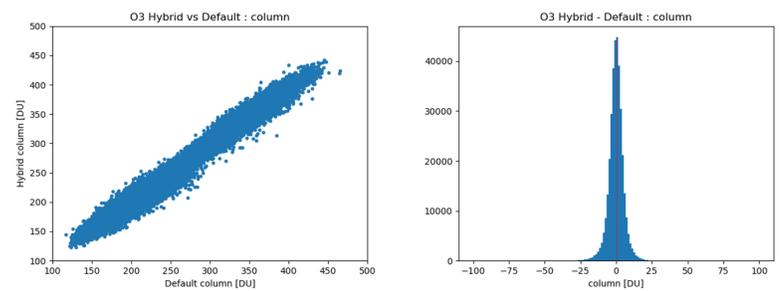
- Overall, the PCA, in most cases, does an excellent job in reconstructing the IASI spectra for exceptional events.
- However, residuals for these events regularly exceed by a large margin the IASI noise.
- The hybrid approach largely improves the reconstruction when the anomalies occur in several spectra (in a plume/larger area).
- The hybrid approach does not help for isolated anomalies.

Ozone retrieval

1 day selected as reference: 11.01.2020



Global maps of ozone columns of 11.01.2020 (am), retrieved from raw L1C radiances (left) and reconstructed radiances with the PC-hybrid approach (middle). Map of the difference (right).

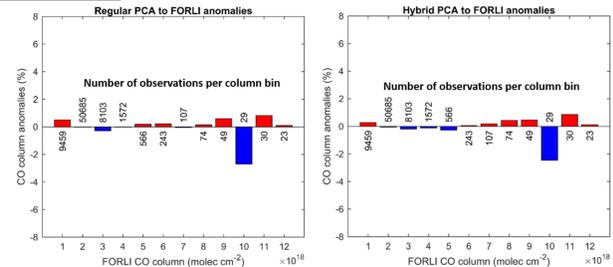


Left: ozone columns retrieved from L1C radiances vs ozone columns retrieved from reconstructed radiances. Right: Histogram of the differences.

- No biases between columns retrieved with Level 1C and reconstructed radiances in standard situations.
- Standard deviation of differences very small as expected.
- Overall excellent agreement with ozone sondes data for standard concentrations, confirming results from 1-day global.
- Therefore, no major issues have been found for the O₃ retrieval from reconstructed radiances.

CO retrievals for strong fire

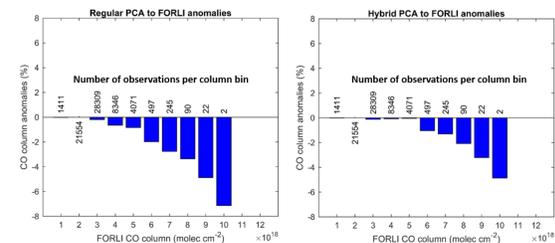
Australian fires: 05.01.2020



Anomalies in the CO columns retrieved from reconstructed radiances with PC-global (left) and PC-hybrid (right) approaches, compared to CO columns retrieved from raw L1C radiances, for the Australian fires of 05.01.2020.

- Overall excellent agreement.
- Therefore, no major issues have been found for the CO retrieval from reconstructed radiances.

Indonesian fires: 03.11.2015



Anomalies in the CO columns retrieved from reconstructed radiances with PC-global (left) and PC-hybrid (right) approaches, compared to CO columns retrieved from raw L1C radiances, for the Indonesian fires of 03.11.2015.

- Overall good agreement for the majority of the observations (bias <1%).
- However there are increasing differences for the largest CO columns, reaching 5-7%. The hybrid approach improves but still leaves a bias of 3-5% for the extreme columns.
- Therefore, there is potentially a problem in extreme CO columns.

Conclusion

Ozone retrieval	• Excellent agreement
CO retrievals for strong fires	• Overall good agreement • Systematic biases for very large CO columns for Indonesian fires
RR for rare events	• Overall good agreement • Some isolated rare signals not well reconstructed

1. The current dual approach to PC (global / hybrid) is generally well-suited for atmospheric chemistry applications in an operational framework.
2. However, in few specific cases, there is room for improvements of the hybrid approach when too large residuals remain, in particular for:
 - some large pollution episodes
 - individual outliers

At the end of this study, an improved hybrid method was successfully tested, where the majority of those outlying spectra are now reconstructed correctly.