Principal Component Analysis of IASI measurements for the detection of extreme atmospheric events

Sarah Pipien (1), Pascal Prunet (1), Claude Camy-Peyret (2,1), Dominique Jolivet (3), Bruno Monsterleet (3), Anne Boynard (1,4), Jean-Baptiste Joan (5), Nicolas Pascal (5), Patrice Henry (6), Laura Le Barbier (6), Thierry Trema (6), Cathy Clerbaux (4)

(1) SPASCIA
Ramonville-Saint-Agne, France
(2) Institut Pierre-Simon Laplace
IPSL/Sorbonne Université, Paris, France
(3) HYGEOS
Lille, France
(4) LATMOS/IPSL
LATMOS/IPSL, Sorbonne Université, UVSQ, CNRS, Paris, France
(5) AERIS/ICARE
Lille, France
(6) CNES, Centre National d'Etudes Spatiales
Toulouse, France

The IASI instruments (on Metop-A, B and C) have provided and are still providing (in the case of IASI-B and IASI-C) more than 10^6 high resolution TIR spectra of the Earth/atmosphere system per day. In addition, European operational atmospheric composition observations from space will benefit from an increasing amount of hyperspectral sounding measurements, including Sentinel 5 precursor (S5P/TROPOMI) and in the near future Sentinel 4 (MTG IRS and UVN), Sentinel 5 (MetOp-SG, with IASI-NG and UVNS) and CO2M. This represents an unprecedented amount of data and a great potential of information in the four spectral, spatial and temporal dimensions.

This paper presents the application and added value of a Principal Component Analysis (PCA) approach to process IASI Level 1 (L1C) measurements, exploiting in near-real-time this 4-dimensional information for the detection of extreme events. Based on extensive experience on the PCA method for compression and noise-reduction of IASI L1C data, dedicated algorithms and tools have been developed for the detection, identification and monitoring of atmospheric extreme events: fires, volcanoes, pollution episodes and other events. The detected extreme events are defined as data outliers with respect to the representative global variability of spectra in normal or unperturbed conditions. The detection is driven by a specific metric of the rarity (infrequency) of any individual spectrum behaviour. This processing has been implemented for the routine processing of atmospheric spectra recorded by IASI-C and for the analysis of IASI -A, -B, -C.

The ability of this processing to deal with both clear and cloudy data for global and extensive monitoring is illustrated. Results of the processing of IASI -A, -B and -C measurements have been analysed. Performances and limitations of this approach for detecting, characterizing and classifying fires and volcanoes, as well as identifying new or unexpected atmospheric signatures in the spectra, are discussed. First results obtained from the systematic, routine processing of IASI-C at AERIS French data center for the year 2024 are also presented.

Finally, this approach has been tested on Short-Wavelength InfraRed (SWIR) spectra measured by S5P/TROPOMI, for evaluating the feasibility and interest of applications to other sounding missions and spectral domains. Perspectives for systematic and automatic processing of these data, as well as the applications for the next atmospheric sounding missions on polar and geostationary orbits, are briefly discussed.