Dust-Devils detection by means of Tomography

C. Aguirre [1](1), Luis Vázquez(2), Rui Vilela-Mendes(3), Raquel Caro(4), María Ramírez-Nicolás (5)
(1) Universidad Autónoma de Madrid, Escuela Politécnica Superior, Calle Francisco Tomás y Valiente 11, 28260 Madrid, Spain.
(2) Universidad Complutense de Madrid, Facultad de Informática, Calle Profesor José García Santesmases 9, 28040 Madrid, Spain
(3) Centro de Matemática e Aplicações Fundamentais, University of Lisbon C6 - Campo Grande 1749-016 Lisboa, Portugal.
(4) Universidad Pontificia Comillas de Madrid, Escuela Técnica Superior de Ingeniería - ICAI, Calle Alberto Aguilera 25, 28015 Madrid, Spain.

Introduction:

Dust devils are important phenomena to take into account in order to understand the global dust circulation of a planet. There are many indications that dust devils role on Mars, could be fundamental and impact the global climate. The capability to identify and study these vortices from the acquired meteorological measurements assumes a great importance for planetary science. Here we present a new methodology to identify dust devils from the pressure time series.

Although the analysis of pressure is usually studied in the time domain, we follow a different approach and perform the analysis in a time signal-adapted domain, the relation between the two being a bilinear transformation, i.e. a tomogram.

A new type of signal-adapted tomogram has recently been proposed by [1] with the detection of dust devils in mind [2]. The signal-adapted tomogram is a linear combination of a standard operator, such as time or frequency with an operator O that is specially tuned to the features of the component that one wants to extract:

$$B(\mu,\nu) = \mu t + \nu O$$

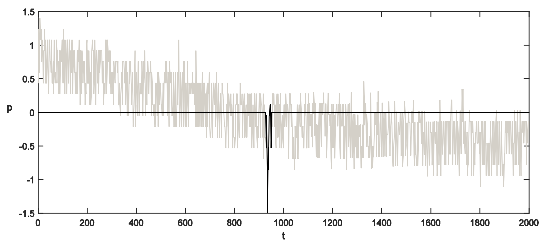
Proceeding in a way like the time-frequency operator, we obtain the N eigenvectors $\{\vec{\psi}_\theta^1, \vec{\psi}_\theta^2, \dots, \vec{\psi}_\theta^N\}$ of an operator $B(\theta)$ obtained from a set of type signals that contain the characteristics of the dust-devil behavior. Projections of the signal $\vec{X}$ on these eigenvectors are obtained by

$$c_\theta^i = \langle \vec{X}, \vec{\psi}_\theta^i \rangle \text{ for } i = 1, 2, \dots, N$$

These projections construct a tomogram adapted to the operator pair t, S.

Once the tomogram is constructed, the signal can be denoised or decomposed just considering only the coefficients with an absolute value over a given threshold $c_\theta^i \geq \epsilon$.

If we consider only the indexes $i = i_1, i_2, \dots, i_h$ for wich $c_\theta^i \geq \epsilon$ we obtain a subset of h coefficients $C = \{c_\theta^{i_1}, c_\theta^{i_2}, \dots, c_\theta^{i_h}\}$. Signal $\vec{x}^f$ is now reconstructed by considering only the vectors $\{\vec{\psi}_\theta^{i_1}, \vec{\psi}_\theta^{i_2}, \dots, \vec{\psi}_\theta^{i_h}\}$ of the tomogram that are in subset C, this is $\vec{x}^f = \sum_{j=1}^{h} c_\theta^{i_j} \vec{\psi}_\theta^{i_j}$



Original $\vec{X}$ (gray) and reconstructed $\vec{x}^f$ (black) signal

References:

[1] Aguirre C., Vilela Mendes R., 2014. Signal recognition and adapted filtering by non-commutative tomography. IET Signal Processing, 8, 67-75..
[2] Gimenez-Bravo A., Aguirre C., Vázquez, L., 2013. Tomographic Signal Analysis for the Detection of Dust-Devils in Mars Atmosphere, The Fourth Moscow Solar System Symposium (4M-S3) IKI RAS, 14-18 October.

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[1] Corresponding author