SVD Analysis of Aura TES Spectral Residuals

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ABSTRACT

Singular Value Decomposition (SVD) analysis is both a powerful diagnostic tool and an effective method of noise filtering.

We present the results of an SVD analysis of an ensemble (~ 500) of spectral residuals (observed - calculated) acquired in September 2004 from a 16-orbit (26 hours) Aura Tropospheric Emission Spectrometer (TES) Global Survey and compare them to alternative methods such as zonal averages.

In particular, the technique highlights issues such as the orbital variation of instrument response and incompletely modeled effects of surface emissivity and atmospheric composition.

Thus it becomes a driver for improving calibration and retrieval algorithms.

Singular Value Decomposition (SVD)

SVD, in the present context, is defined by the expression

$$\mathbf{S} = \mathbf{U}.\mathbf{W}.\mathbf{V}^{\mathbf{T}}$$

Where **S** is matrix of **m** spectral residuals each comprising **n** spectral elements,
U is an **m** x **m** orthogonal matrix (essentially the space/time order of the spectra),
W is an **m** x **m** diagonal matrix containing the *singular values* and
V is an **m** x **n** orthogonal matrix containing the decomposed spectral residuals.

In our case, **n** = 6166 and **m** = 568.

SVD Filtering

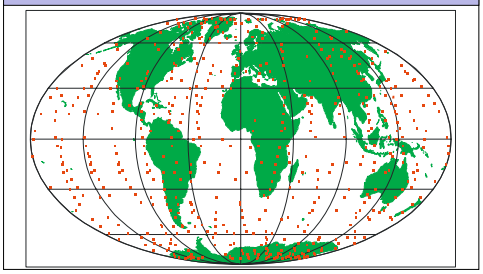
SVD filtering is accomplished by selecting the first few significant values of **W** (sometimes called the *Principal Components*) and setting the rest to zero.

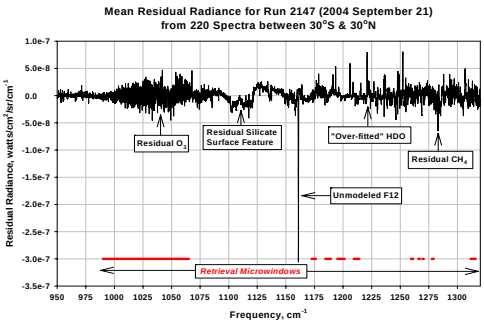
The expression on the previous chart is then solved in the forward direction to provide a revised version of **S** (**S'**, say).

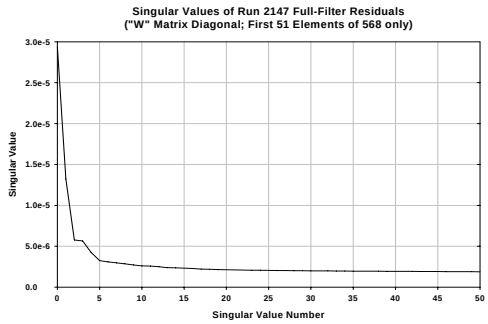
S' is the SVD filtered result.

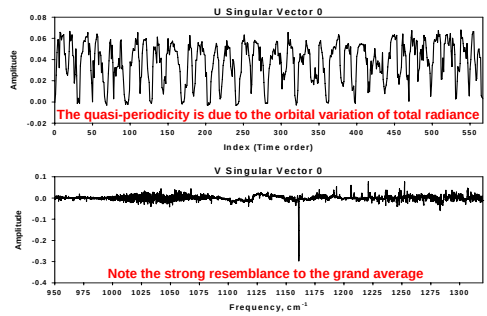
What constitutes a "Principal Component" is, of course, a matter of judgment. For this exercise, we have selected the first 10 singular values.

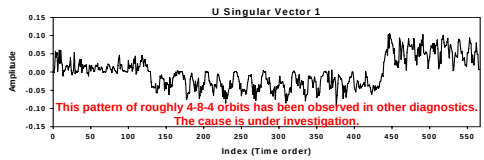
Location of Observations Used

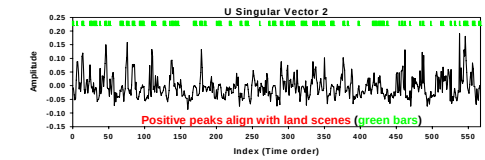


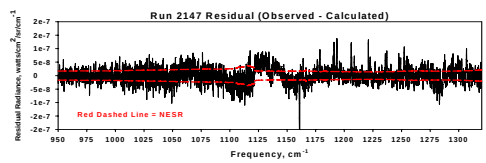


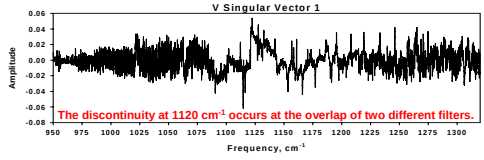


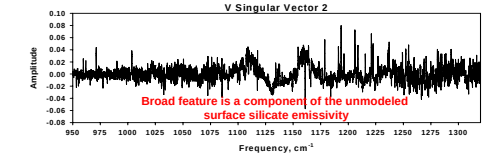


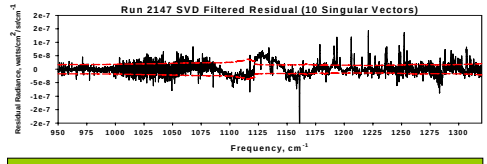












Example of an unfiltered and SVD filtered spectral residual (acquired 31°N, 131°E)

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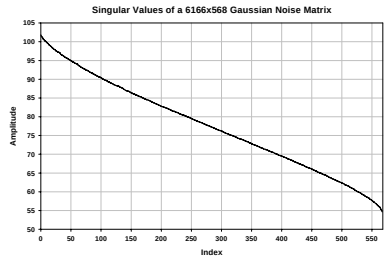
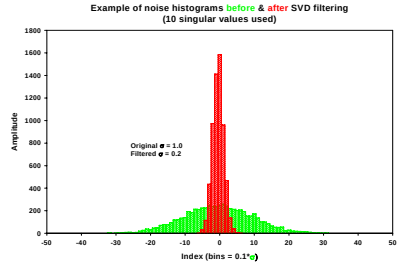
A CONTROLLED EXPERIMENT

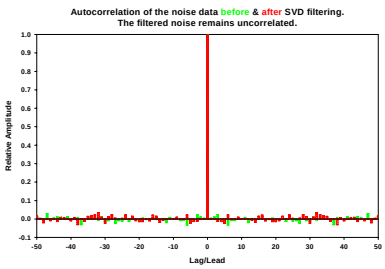
METHOD

We created a matrix identical in size to the observation matrix, but populated with pseudo-random Gaussian deviates. The result was first subjected to the identical analysis to that presented earlier.

The standard deviation was, indeed, reduced but without any obvious correlations being introduced, so (since no-one believes in "something for nothing") where is the catch?





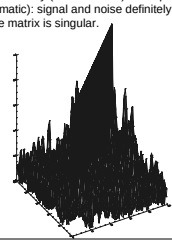


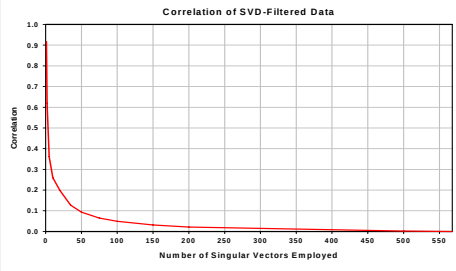
HERE'S THE CATCH!

The "catch" becomes evident when this noise array (random error) is coupled to the singular vectors of the real data (systematic): signal and noise definitely become correlated so the resultant error covariance matrix is singular.

To the right is an example of a correlation matrix using the first 150 (out of 568) singular vectors.

The diagonal is clearly visible, as are the off-diagonal elements.





The metric for correlation is the mean absolute value of the off-diagonal elements

Future Work

Attempt retrievals on SVD filtered spectra

- Conjecture: little or no improvement will be observed because measurement error (noise) is not usually the dominant error source.

- Furthermore, the singularity of the error covariance will cause difficulties with the error analysis.

- However, it may permit a reduction in the size of some of the larger microwindows with a concomitant improvement in speed.

Conclusions

1) Singular Value Decomposition is undoubtedly a very useful tool for diagnosing spectra and spectral residuals because unmodeled phenomena and calibration issues become very visible.

2) Whether this will permit improved retrievals is a topic of ongoing research. However, it must be noted that the process is computationally-intensive so it is unlikely to be used in routine production.

Acknowledgements

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