Small Signal Demo

To demonstrate Toolkit capabilities to detect amplitude and phase-modulated oscillations with a very low signal to noise ratio, we use here the test dataset of Allen and Smith (1996), for more information see **http://www.atmos.ucla.edu/tcd/ssa/guide/users.guide4.demo.html.** This synthetic test series consists of two damped oscillations bursts superimposed on large amplitude AR(1) noise. The period of the oscillations is 5.5 units, which corresponds to the frequency f=0.181. Our task will be to identify this weak oscillation signal in this data.

This directory includes following files:

noise: red-noise component of **data;**
signal: oscillatory component of **data;**
data: sum of noise + signal.

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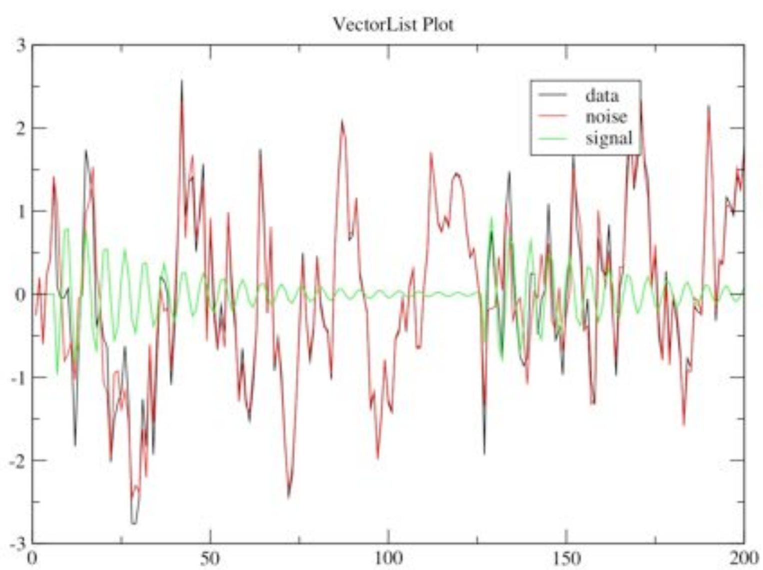
1. Loading & plotting the data:

Double-click **Spectra** , go to **File/Data->Read Vector;** navigate to the folder **SUMMER_SCHOOL/SIGNAL,** select file **data** in **Files** panel, change name in "***Store data in vector***" field to **data**, and click **Read file**.

Repeat this procedure with the **noise** and **signal** files, storing them into vectors with the names **noise** and **signal,** respectively**.**

Go to **Plot -> Vector List,** add **data, noise** and **signal** vectors to a list, and then click **Plot** to examine the data.

Figure 1 (print to a file).



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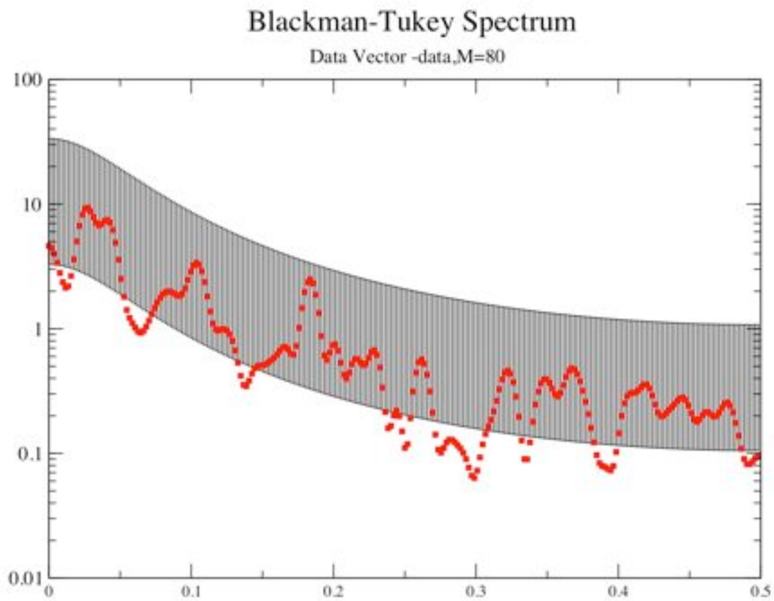
2. "Standard" Spectral Methods (BK-Correlogram):

Go to **B-T Correlogram** in **Analysis Tools,** select **data** from **Data** Pop-up menu, click **Default** to set default parameter values, change the **Window** value to **80**, set **Confidence levels** to **AR(1)** and then click **Compute**, followed by **Plot.** Observe that there are a number of peaks in the spectrum that do not go above confidence levels. Change the **Window Size** to **40** and **120** as well as its type to see the difference in the spectral estimates. Recall that larger window size improves resolution but at the cost of increasing variance of the spectral estimates. Conclude that we have to use **SSA** and **MTM** tools in order to identify the presence of embedded oscillatory signal.

Figure 2 (print to a file).



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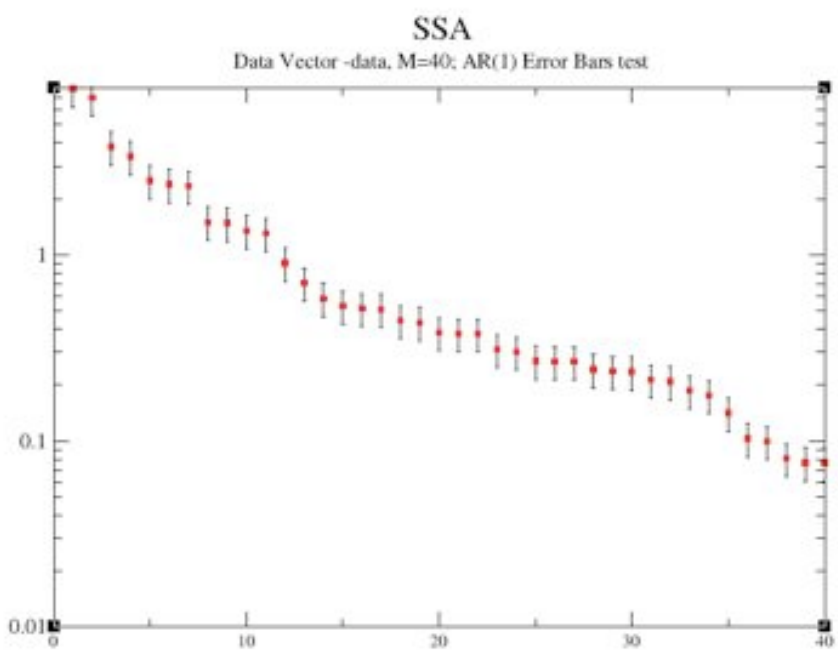
3. "Advanced" Spectral Methods (SSA):

Go to **SSA** in **Tools,** select **data** from **Data** Pop-up menu, click **Default** to set default parameter values, change the **Window** value to **40**, and SSA components to **11**, **Error bars** as **Significance Tests**. Click **Test Options** and check **`Same Frequency'** and **'Strong FFT'** boxes. Now click **Compute** and **Plot.**

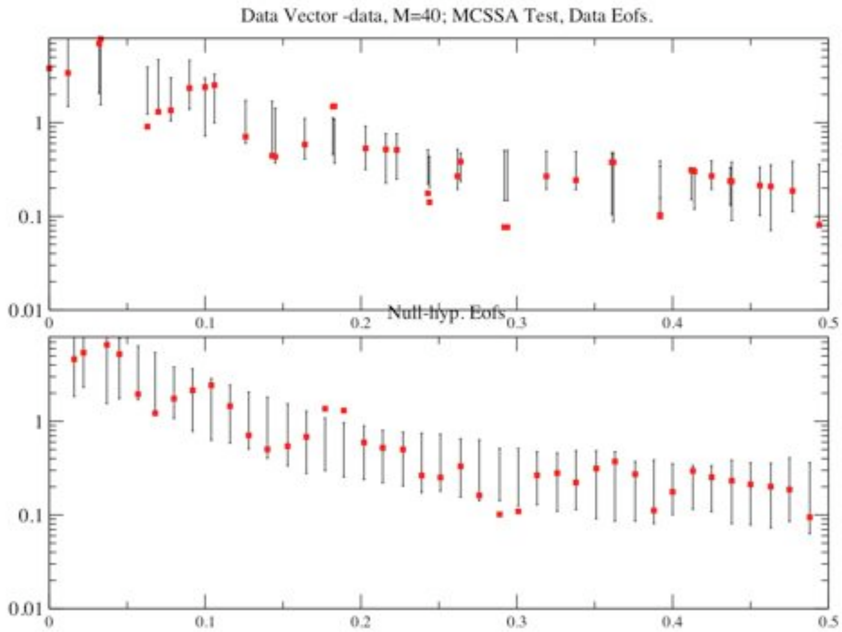


The oscillatory pair is 8-9, but the **Log file** shows that two additional pairs falsely pass the significance test (1-2 and 10-11)!

Now set **Monte Carlo** as **Significance** test. Click **Test Options** and change **Ensemble size** for the number of Monte-Carlo red-noise realizations to **500**, check **`Same Frequency'** and **'Strong FFT'** boxes as well. Then click **Compute**, followed by **Plot.** Notice there is a clear oscillatory pair at the right frequency **=0.18** of the signal for both **Data Eofs** and **Noise Eofs (Null-hyp. EOFs).**

The Null-hyp basis avoids artificial variance compression towards low-frequency part (i.e. "large" vs. "small" spatial patterns in EOF analysis) in SSA and therefore it has a lower probability of false-positive results, i.e. identifying the noise components as significant, i.e. for the leading pair (1 2) of SSA components for both Data EOFs test and by `Same Frequency' and **'Strong FFT'** tests in the **Log file!!!**

Figure 3 (print to a file).



Repeat SSA, but with **Chi-squared** as **Significance** test and different **Covariance** types. Notice how much faster is the computation! Compare the results with Monte-Carlo test.

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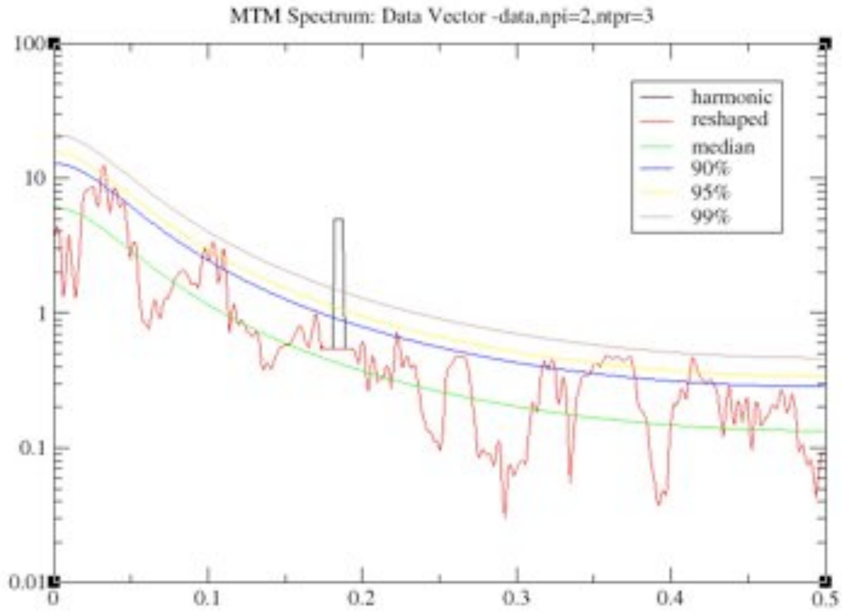
4. "Advanced" Spectral Methods (MTM):

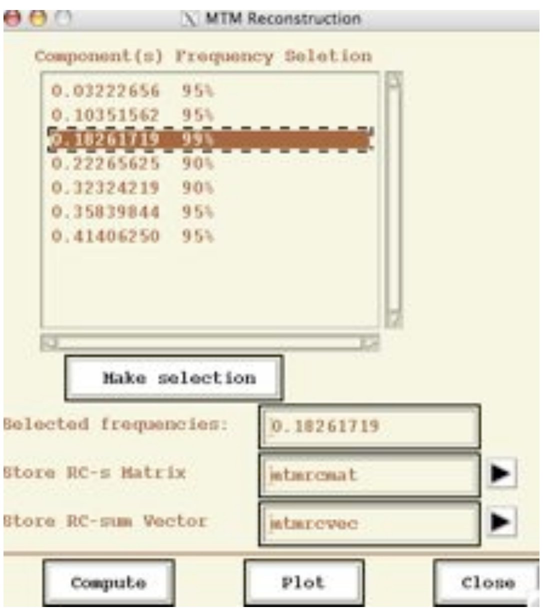
Go to **MTM** in **Tools,** select **data** from **Data** Pop-up menu, click **Default** to set default parameter values.Recall from the SOI example that **``Reshaping''** procedure is used to separate the continuous and harmonic portions of the spectrum which is our goal here. Go to **MTM Options** and set **Signal Assumption** to **Either**, to test the spectrum for **both** the presence of **narrowband** signals whose significance is measured by their amplitude relative to the estimated noise background (**red-noise** by default), and for the presence of **``harmonic''** signals which are significant as measured by the Thomson variance ratio test for periodic signals **(F-test** against the white noise). In **`Reshape Threshold''** menu change the threshold for significance of harmonic peak detection (**`F-test'')** from its default setting of **95%** to **99%**. Since the **Signal Assumption** option is set to **Either**, the detected **harmonic** peak (**`F-test'')** will be **reshaped** only if it is **ALSO** signficant to the **estimated noise background** at a **Reshape Threshold** level of **99%** also, which is a more stringent test than doing either **Narrowband** or **Harmonic** alone.

Now click **Compute,** followed by **Plot**. Notice how reshaping of the spectral peak at the correct frequency f=0.18 confirms **SSA** findings.

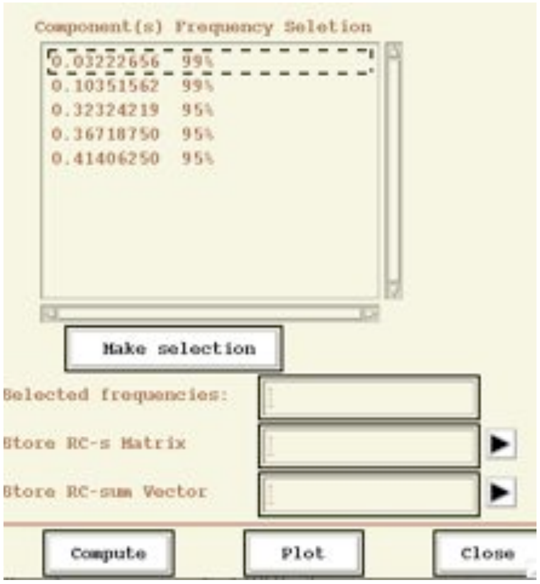
Figure 4 (print to a file).

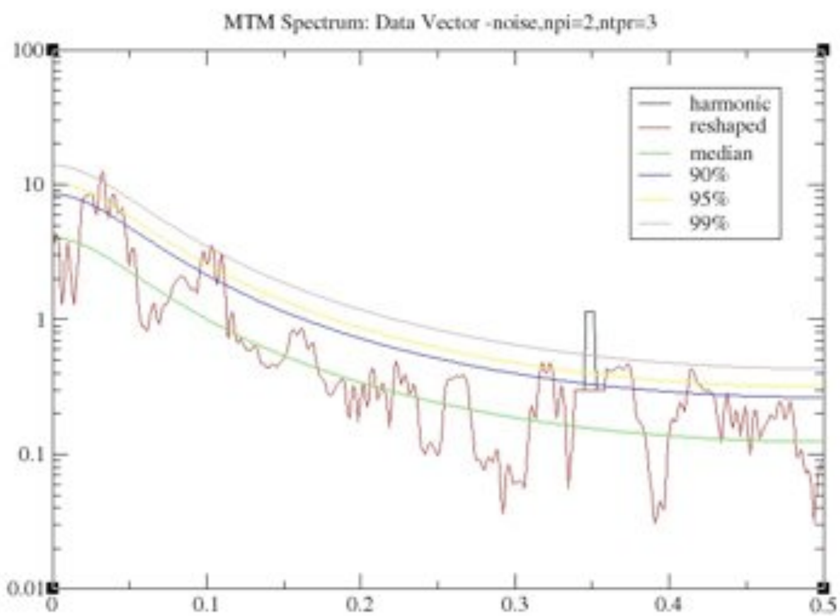


Now go to the **Reconstruction.** Since **Signal Assumptions (in Test Options**) is set to **Either**, the **Component(s) Frequency** in **Reconstruction table** will contain a list of the central frequencies of **narrowband signals** identified as significant at greater than the 90% level relative to the specified null hypothesis (red-noise by default). There is only one frequency (correct one a**t f=0.18**) that is significant at 99%!



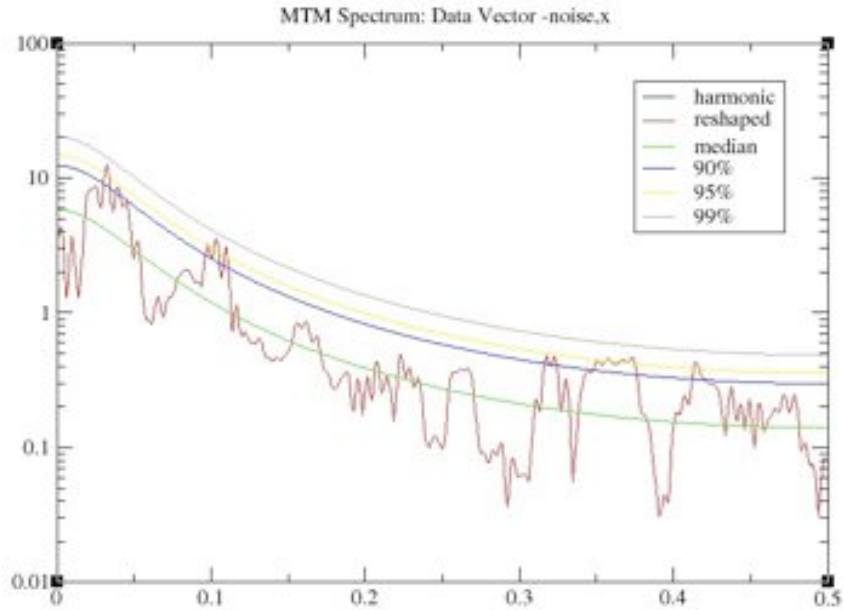
Now repeat MTM analysis with the **noise** vector using the same MTM settings as for the **data**, you should get the following (false identifications) :





Play with MTM settings to **get rid of false high significance results for noise,**

Figure 5 (print to a file)


MTM Spectrum: Data Vector -noise,x
harmonic
reshaped
median
90%
95%
99%
100
10
1
0.1
0.01
0
0.1
0.2
0.3
0.4
0.5