

Figure 2: Two synthetic seismic phases. (a) Original RS. (b) Filtered RS with $M = 9$

4 Conclusion

We have presented a new method for adaptively filtering RS depending on the instantaneous slowness of seismic phases. The proposed method works efficiently even in a non-stationary context, being completely adapted to any specific signal trajectory and preserving the other signals with minimal distortion. This makes possible to analyze weaker signals and to extract much more information from seismic RS.

5 Acknowledge

This work was supported by the project SigSensual CTM2004-04510-C03-02 and NEAREST CE-037110, M. Schimmel is supported through the Ramon y Cajal and the Consolider-Ingenio 2010 Nr. CSD2006-00041 program.

References

- [1] O. Yilmaz and S. M. Doherty, "Seismic data analysis: processing, inversion, and interpretation of seismic data," SEG, 2001.
- [2] S. Ventosa, C. Simon, M. Schimmel, J. Dañobeitia, and A. Mánuel, "2-D coherent signal processing: The adaptive slowness approach," IASTED 2007.
- [3] W.H.Press, S.A.Teukolsky, W.T.Vetterling, and B.P.Flannery, "Numerical recipes in C: The art of scientific computing," Cambridge University Press, 1992.

COMPARATIVE RESPONSE OF TWO DIFFERENT HYPERSENSPECTRAL SENSORS. APPLICATION TO DERIVATIVE ANALYSIS OF ABSORPTION SPECTRA

E. Torrecilla (1), S. Pons (1), I. Fernández (2), J. Piera (1,2)

(1) Marine Technology Unit (CMIMA-CSIC).
932309500 torrecilla@utm.csic.es.

(2) Dept. of Signal Theory and Communications. Technical School of Castelldefels (UPC).

1. Introduction

A broad range of in situ and remote hyperspectral sensors, covering from several hundreds to thousands spectral bands, have been developed recently for different environmental monitoring applications. Several studies using hyperspectral data and derivative spectroscopy have been done so as to assess qualitative and quantitative information about water components [1]. One of the key aspects to take into account is the processing techniques applied to raw spectral data to get comparable results between different measurements.

The commonly derivative spectroscopy used to explore subtle features in spectral data is notoriously sensitive to noise [2]. Noise level in hyperspectral data is high as their narrow bandwidth can only capture very little energy that may be overcome by the self-generated noise inside the sensors. To remove the noise from hyperspectral data smoothing techniques are commonly used [3]. However, for preserving the properties of the original data, smoothing and derivative techniques should be carefully applied to minimize possible numerical artifacts. There is a trade-off between noise removal and the ability to resolve fine spectral details. The main factor controlling the extent

of smoothing is the size of the filter window used for averaging or convolution. The greater the size of the filter window, the smoother the result. The spectral details revealed in the derivative spectra are a function of the band separation ($BS=\Delta\lambda$). Features smaller than $\Delta\lambda$ will be lost and features at the scale of $\Delta\lambda$ will be enhanced.

In the present study, a comparison between the spectral data obtained using two hyperspectral sensors with different spectral resolution is exposed. Smoothing and derivative algorithms have been applied to both types of spectral data in order to assess qualitative information from their spectral features.

2. Results and Discussion

Two different hyperspectral sensors have been employed: the Ocean Optics USB4000 Spectrometer, that uses the Toshiba TCD1304AP 3648-element linear CCD-array detector and the MicroParts GmbH UV/VIS Microspectrometer, a lower cost and lower energy-consuming device more suitable for being part of a node in a monitoring sensor network [4], that uses the Hamamatsu S8378 256-element linear CMOS-array detector.



The spectral characterization of an algal culture with different concentration rates has been used for comparing the results obtained. The algal culture corresponds to a dinoflagellate capable to form toxic blooms with paralytic shellfish poisoning (PSP). Nowadays, there is an increasing interest in monitoring the dynamics of harmful algal blooms (HABs) using non-invasive techniques, such as those based on spectral methods.

Hyperspectral derivative analysis has been applied to all spectra using several MATLAB modules [2]. Before that, in order to minimize the effect of the light source fluctuations, all spectra have been normalized to a reference. Additionally, all spectra have been smoothed using a mean filter. The size of the filter window for averaging has been selected according to the spectral resolution and the signal-to-noise ratio of each sensor.

Second order derivative spectra have been computed. Peaks in the derivative are associated with absorption bands due to pigment composition of the algal group considered and its height is commonly used in estimating pigment concentrations [5]. The importance of selecting a suitable band separation (BS) stems from the facts that spectral data features narrower than the band separation will be lost and that a smoother derivative spectra is obtained as the band separation increases.

Attenuation spectra collected using the USB4000 spectrometer have been measured from 178.72 to 888.19 nm in 3648 channels (spectral resolution approx. 0.19nm/channel). The smoothing algorithm has been applied with a filter size of 21 points and the derivative analysis has been calculated with an optimal band separation (BS) of 25 samples. In case of using the MicroParts spectrometer, the spectra have been collected in 256 channels, from 307.96 to 1100 nm (spectral resolution approx. 3nm/channel). The derivative analysis has been calculated with the narrowest band separation (1 sample) and a smoothing filter size of 1 point. For each algal concentration rate and by each sensor, a total of ten measurements were made. Mean spectra were then calculated and are displayed in Figures 1A and 1C.

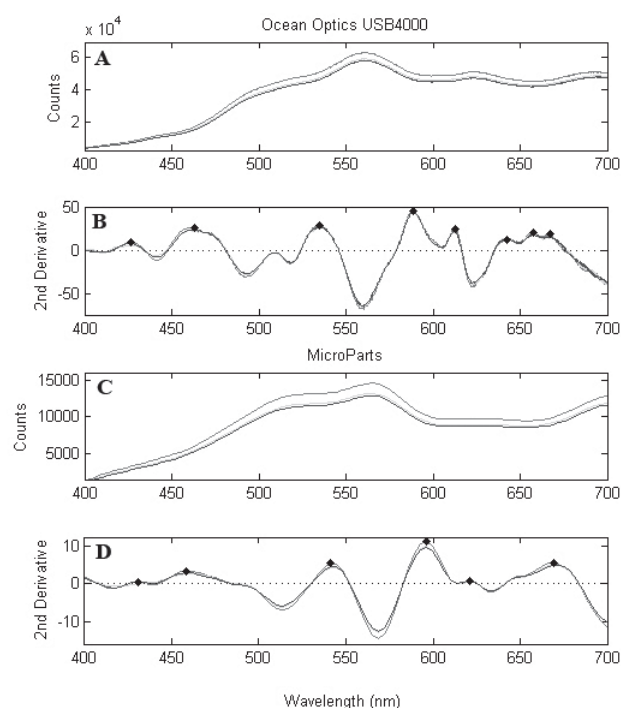


Figure 1. Original spectral data (A), (C) and 2nd derivative spectra (B), (D).

can be seen, magnitude of the USB4000 and MicroParts spectra tend to decrease as the algal culture concentration rate is increased. Second derivative spectra from USB4000 and MicroParts data (Figures 1B and 1D) reveal a combination of peaks corresponding to absorption features related to pure water, pigments like chlorophyll-a and a variety of accessory pigments present in the samples. All peak positions fulfill the criteria of the occurrence of an absorption band described by [6]. Despite slight shifts in wavelength position, most of the peaks have been detected with both hyperspectral sensors, except for the wavelength range of 640-670nm. Therefore, qualitative and quantitative information regarding pigment composition of the considered algal culture can be obtained based on the wavelength position and height of the peaks in the USB4000 and MicroParts derivative spectra.

In order to estimate the pigment composition regardless of the sensor used, interpolation techniques have been used up to now to match spectral resolutions of data. USB4000 spectral data has been decimated to match the MicroParts data resolution, whereas MicroParts spectral data has been interpolated using a cubic spline interpolation so as to match the USB4000 data resolution. The position of derivative peaks obtained has not differed significantly.

3. Conclusions

The preliminary results point out the importance of selecting the optimum working parameters (window filter size and band separation) when hyperspectral smoothing and derivative spectroscopy are used. The results obtained with the MicroParts hyperspectral sensor confirm this type of microspectrometers as a potential tool for water component monitoring.

4. References

- [1] E.M. Louchard, P. Reid, C.F. Stephens, C.O. Davis, R.A. Leathers, T.V. Downes and R. Maffione, Derivative analysis of absorption features in hyperspectral remote sensing data of carbonate sediments, *Optics Express*, vol. 10, no. 26, 2002.
- [2] F. Tsai and W.D. Philpot, Derivative analysis of hyperspectral data, *Remote Sensing of Environment*, vol. 66, no. 1, 1998.
- [3] C. Vaiphasa, Consideration of smoothing techniques for hyperspectral remote sensing, *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 60, no. 2, 2006.
- [4] S. Pons, I.F. Aymerich, E. Torrecilla and J. Piera, Monolithic spectrometer for environmental monitoring applications, *IEEE/OEE Oceans Conference and Exhibition*, June 2007.
- [5] D.F. Millie, O.M. Schofield, G.J. Kirkpatrick, G. Johnsen, P.A. Tester, B.T. Vinyard, Detection of harmful algal blooms using photopigments and absorption signatures: A case study of the Florida red tide dinoflagellate, *G. breve*, *Limnology and Oceanography*, vol. 42, no. 5, pt. 2, 1997.
- [6] R.L. Huguenin and J.L. Jones, Intelligent Information Extraction from Reflectance Spectra: Absorption band Position, *Journal of Geophysical Research*, vol. 91, 1986.

