Derivative spectroscopy with HICO®

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Abstract: The Hyperspectral Imager of the Coastal Ocean — HICO® — is a visible and near-IR grating spectrometer currently in orbit on the International Space State (ISS) [1]. HICO's 5.7 nm (binned) spectral resolution permits the application of derivative spectroscopy to the identification of remotely sensed water constituents. We examine applications of derivative spectroscopy to complex coastal waters with riverine inputs such as the Columbia and Yangtze rivers.

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1. Background

Remote sensing ocean imagers are designed to capture a dark object (water) in a bright background (atmosphere). The current generation of ocean imagers are 'multispectral,' and product algorithms are tuned to make use of the of the distinct spectral channels. As demonstrated by HICO [2] , however, current technology permits the design of low-noise space bourne spectrometers with continuous spectral coverage, as well as enhanced spatial coverage. HICO's typical ground sampling distance is 90 meters with a native spectral resolution of 1.9 nm, which is typically binned up to 5.7 nm. Useable spectral coverage ranges from 400 nm to 900 nm.

Derivative spectroscopy is a useful technique for the routine analysis of laboratory spectra. Derivative spectroscopy is also useful in the identification of informative remote sensing channels to aid the design of multispectral imagers [3], and initial applications also show its utility in the identification of shallow water bottom types [4].

Multispectral imagers focus on the extrema spectra of water or atmospheric constituents. Hyperspectral instruments and derivative spectroscopy allows us to quantify the shape and curvature of spectral peaks as well. For instance, the half-width of a fluorescence peak is amplified by the use of derivative spectroscopy. A peak with a smaller half-width will have a larger derivative around the maximum, and this spectral feature which is emphasized in the derivative can be used to distinguish and identify spectral features.

Care must always be taken in the numerical computation of derivaties to minimize the the impact of noise amplification. We compute the derivatives using a Savitzky-Golay filter [5]. At the same time we interpolate the data to a uniform 5 nm spacing. HICO has a signal-to-noise (SNR) of about 400 in the blue and 200 in the red [2]. To further reduce the noise in the data, where appropriate, we spatially bin the data to larger pixel sizes to further increase the SNR. Spectral features are identified by first looking at the extrema and zero crossings of the derivatives, but further analysis also includes the calculation of principal components to try to match the remote sensing spectra to lab measurements of probable minerals or pigments [6].

2. Applications

As a first example we examine an image of the Columbia River from May 2012 (Fig. 1). The fourth derivative is often used since it has the same extrema as the original spectra (the second derivative also has the same extrema but with the minimums and maximums interchanged). Pixels are chosen which are thought to represent different water masses, and the derivative is examined (Fig. 1 (c)) to find features that are used to distinguish the water masses. Then these channels can be chosen for the RGB composite to highlight differences. In this example it appears that that there are three distinct water masses, presumably occurring from sediments at three distinct depths due to tidal forcing. Choosing, for instance, a channel near 610 nm allows us to separate older water outflowing from the Columbia (red dot in Fig. 1 (a)) from newer water (green dot in Fig. 1(a)). Picking RGB channels to separate water masses results in the image Fig. 1(b). Thus, in this very simple application, we illustrate how a derivative signature can be used for image enhancement.

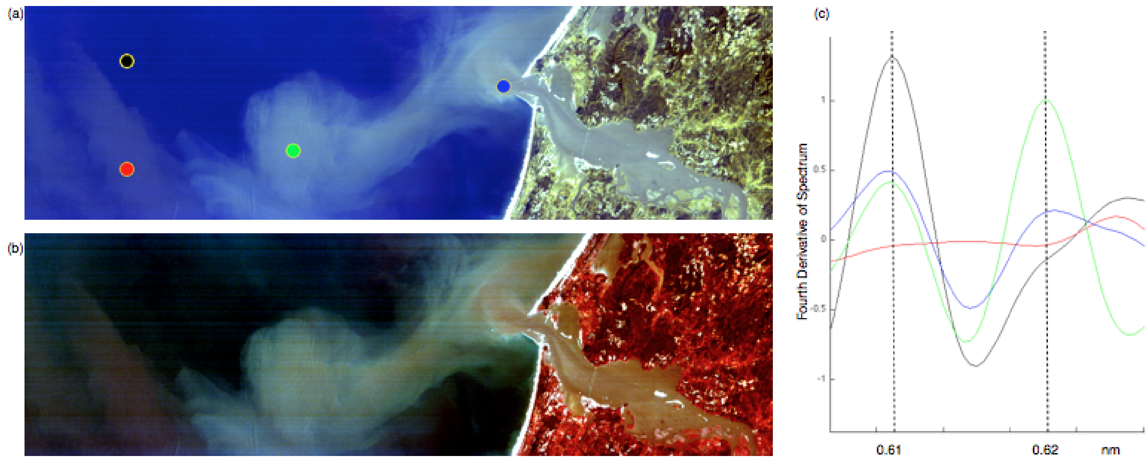

Fig. 1. HICO image of the Columbia River from 12 May 2012, 1:05 GMT. (a) RGB image of river outlet, (b) enhanced image highlighting plume structure, (c) use of derivative analysis in selection of channels sensitive to plume sediments.

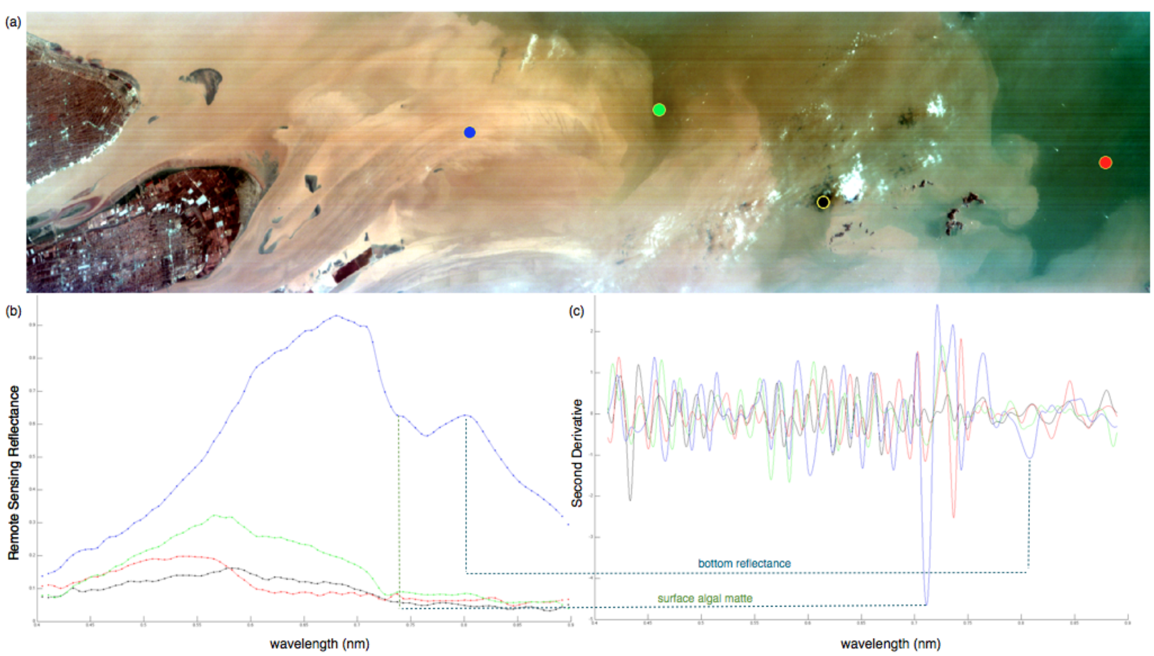

Fig. 2. HICO image of the Yangtze River from 28 March 2012, 0:47 GMT. (a) RGB image of river outlet, (b) Atmospherically corrected spectra, (c) derivative analysis highlighting channels sensitive to bottom reflectance and algal mattes.

As a second example consider the sediment rich outflow from the Yangtze river in March of 2012 (Fig. 2). The average total dissolved solids (TDS) out of the Yangtze exceeds 250 mg/L, and causes a tan colored fan shape in the East China Sea easily seen from space. Atmospherically corrected spectra are shown in Fig. 2 (b). Salient features such as a peak of 800 nm from bottom reflectance and a peak at about 710 nm from a surface algal matte are highlighted in the second derivative (Fig. 2(c)). Although the bottom reflectance is easy to see in the original spectra (Fig. 2(b)), the 710 nm peak is not readily apparent, but is prominent in the second derivative plot (Fig. 2(c)).

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