



Conference Proceedings Paper – Remote Sensing

Testing a New Approach for ASTER Image Data Sharpening via Using Diverse Principle Components

Jan Jelének^{1,*}, Veronika Kopačková^{1,†} and Lucie Koucká^{1,†}

¹ Czech geological survey, Klárov 3, Prague 1, Czech Republic; E-Mail: jan.jelenek@geology.cz, veronika.kopackova@geology.cz, lucie.koucka@geology.cz;

[†] These authors contributed equally to this work.

* Author to whom correspondence should be addressed; E-Mail: jan.jelenek@geology.cz; Tel.: +420-257-089-438; Fax: +420-257-531-376.

Published: 22 June 2015

Abstract: Image data sharpening is a widely used method to increase a spatial resolution of images with a higher spectral and lower spatial resolution. In our study we focused on sharpening ASTER image data using a high spatial-resolution panchromatic band of WorldView-2 data. Both datasets were acquired within the framework of a geological mapping project in the southwest Mongolia. Primary remote sensing task was to produce mineral maps for the studied area. ASTER data providing several bands in the short wave infrared (SWIR) spectral region has a great potential for geological/mineral mapping. On the other hand, a spatial resolution is rather coarse for the geological mapping at a 1: 50, 000 scale. ENVI and Erdas Imagine software (SW) were used to test the available Principle Component Analysis sharpening algorithm; however satisfactory spectral mapping results have not been achieved. In the commercial SW, the first component (PC) is used for the sharpening process by default, but the 1st PC usually does not contain the main spectral variability considering mineralogy/geology. Therefore, a new approach using the other principal components for image sharpening was tested and compared with the approach available in the commercial SW. New processing was developed in the ENVI software.

Keywords: Pansharpening; PCA; ASTER; WorldView-2

1. Introduction

Image data sharpening is a challenging field of remote sensing science which became more popular after recent emergence of high spatial resolution satellite image sensors. Those satellites usually provide one broad-band panchromatic (PAN) band with a high spatial resolution and multispectral images with lower spatial resolution. The general approach is to use the PAN band to enhance spatial resolution of the multispectral images using sharpening algorithms which are using different algorithms to inject the spatial detail of the PAN image to the higher spectral resolution image data.

Generally, sharpening algorithms can be divided by several means (e.g., [6], [8]). First group can be described as component substitution algorithms (CS). The most prominent algorithms of this group are Principal component analysis (PCA), Intensity-hue-saturation (HIS), Gram-Schmidt transform (GS), Ehlers fusion (EF) or Brovey transform (BT). Those algorithms have advantage in low computing time, easy implementation and great visual interpretive quality, although they are lacking spectral accuracy [1], which is important for most remote sensing applications based on spectral signatures [3]. To improve spectral accuracy in the sharpened images, algorithms based on discrete wavelet transform (DWT) had been developed. Those belong to the second group of sharpening algorithms [7]. As described in [8], multi-resolution analysis approaches are good in preserving spectral information but they are not capable to preserve object contours and general spatial smoothness on the other side. Therefore several improvements in the wavelet transform had been introduced, such as Undecimated DWT or Non-subsampled contourlet transform (NSCT). Algorithms of those two groups can be combined to choose the best of each. The best example can be the combination of the PCA and the contourlet transform [5].

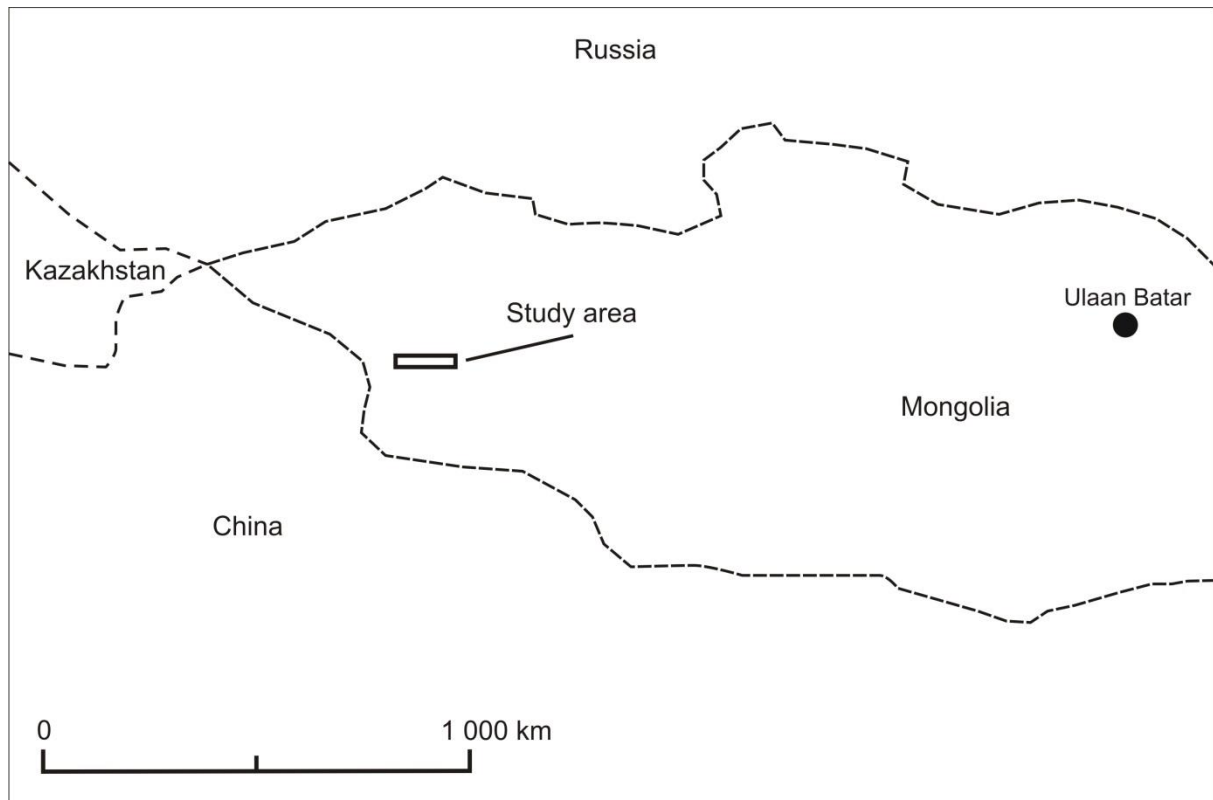
As has been already mentioned, CS algorithms are popular mainly because of the easy implementation, broad availability in most popular software and low computational time. Algorithms of the CS are also designed to produce visually great results characterized with sharp edges and preserving well spatial features. In our study we adopted the PCA algorithm (PC Spectral Sharpening method, [2]), as belonging to those most-widely used.

In PAN sharpening techniques, a broad panchromatic (PAN) band characterized with a high spatial resolution is used to sharpen the multispectral (MS) data, these are characterized with a coarser spatial resolution on one side but with a better spectral resolution on the other side. The principal component technique (PCA) is performed to compress the spectral information of MS data into a couple of principle component bands (PCs), these can be then resampled to high spatial resolution of the PAN band. In the available software (SW) only the 1st component is used by default for the sharpening process. This may not be optimal if mineral spectral mapping is demanded, as the PC1 contains mainly the information on surface albedo but doesn't contain much information on mineral spectral variability. Therefore, we adopted the PC Spectral Sharpening method and tested if the PCs of a higher order (e.g., PC2, PC3 etc.) will improve a spectral performance of the sharpened ASTER images.

We tested the new concept using the ASTER image data (representing the MS bands) and the WorldView-2 panchromatic data (PAN band) for image fusion. In previous literature there is a limited number of the studies using this type of data for image fusion [4]. Although spectral resolution contributes the most to the mineral mapping using image data, spatial resolution is the key factor to identify/interpret targeting minerals/rocks in a spatial context. Therefore, improving a spatial context

while keeping the spectral property of the ASTER data would bring great benefits for geological/mineralogical mapping in arid environments.

Figure 1. Location of the study area.



2. Satellite data

To support the geological mapping, data from two different platforms/instruments, ASTER (Terra satellite) and WorldView-2, were employed. ASTER (Figure 2) dataset consists of 9 optical bands with spatial resolution from 15 (VNIR) to 30 meters (SWIR). Data were acquired on the 3rd March 2005 and were provided by the Japan Space Systems. WorldView-2 (WV2) dataset consists of one PAN band with a spatial resolution of 0,5 meter. The orthorectified WV2 data were acquired on the 22nd March 2012 and were provided by the DigitalGlobe, Inc. Specifications of both satellite datasets are summarized in the Table 1. ASTER data was orthorectified and converted to reflectance values using Atcor 2 software.

Primary remote sensing objective was to produce mineral maps for the areas of the interests. ASTER data provides several bands in the short wave infrared (SWIR) spectral region and therefore has a great potential for geological and mineral mapping. On the other hand, a spatial resolution is rather coarse for the geological mapping at a 1: 50,000 scale. WorldView-2 data provides one of the highest spatial resolution available nowadays. Spatial and spectral fusion of both datasets would earn significant benefits to the remote sensing applications in geology, because it would combine ASTER's strong spectral property and WorldView's strong spatial property.

Figure 2. A study area (ASTER image data, RGB bands B3, B2, B1).



Table 1. Technical specifications of the two image datasets used in the study.

Sensor name	Band name	Spectral range [μm]	Resolution [m]
ASTER	B1	0,52 – 0,6	15
	B2	0,63 – 0,69	15
	B3	0,76 – 0,86	15
	B5	1,6 – 1,7	30
	B6	2,145 – 2,185	30
	B7	2,185 – 2,225	30
	B8	2,235 – 2,285	30
	B9	2,295 – 2,365	30
	B10	2,36 – 2,43	30
WorldView-2	PAN	0,45 – 0,8	0,5

3. Experimental section

In this study, the PCA sharpening method was adopted mainly because it's broad availability throughout the remote sensing software (SW). General principle of the PCA method is to transform the multispectral image bands, which are usually intercorrelated, into the newly constructed multidimensional space. Original image bands are transformed into the new uncorrelated components which are constructed in the way to keep highest variance of the original data and to contain the most amount of the information from the original image [5]. Consecutively, each following component (PC) has the 2nd, 3rd, etc. highest variance in the n-dimensional space. All components are perpendicular to each other in the n-dimensional space.

In the SW available users cannot manually edit parameters of the sharpening algorithm, such as choice of the principal component to be substituted, which makes the sharpening process inflexible to the wide variety of applications and input data. The default setting in available SW uses the first component (1st PC), as it contains the biggest information variance but this is mainly the information on surface albedo. On the other hand, the 1st PC does usually not contain the spectral variability considering geology and mineralogy.

The main objective was thus to test if the other PCs used in the sharpening process can preserve better the geological/mineral spectral information when if the 1st PC is being used. Each of the principal components (PC1-PC9) was used to compress the spectral information and to be consequently spatially sharpened using the PAN WV2 band. Results were spectrally compared with the image sharpened by the 1st PC (the default option in SW). In the workflow, each principle component (PC1-PC9) sharpened by the PAN band has to undergo histogram matching and inverse PCA transformation is then applied using statistics from the forward PCA transform. Detailed workflow diagram is presented in the Figure 3. For the spectral evaluation, three different surfaces were chosen (Figure 4): two types of rock (amphibolitic rock and silicates) and dried riverbed.

Figure 3. Processing scheme (MUL: multispectral ASTER data, PAN: panchromatic WV2 band, PC: Principal component, PCA: Principal component Analysis).

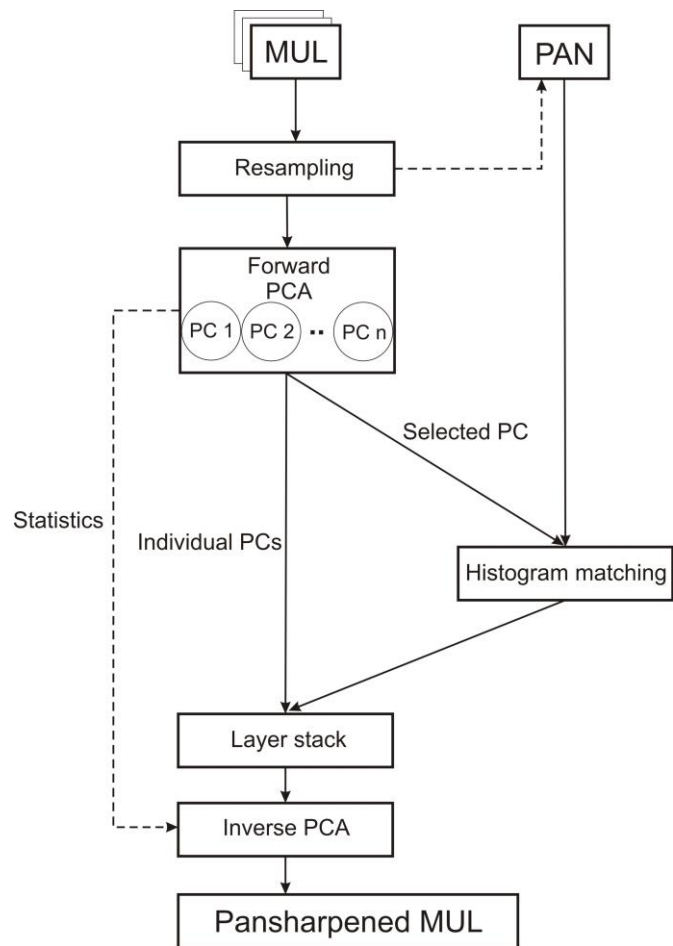
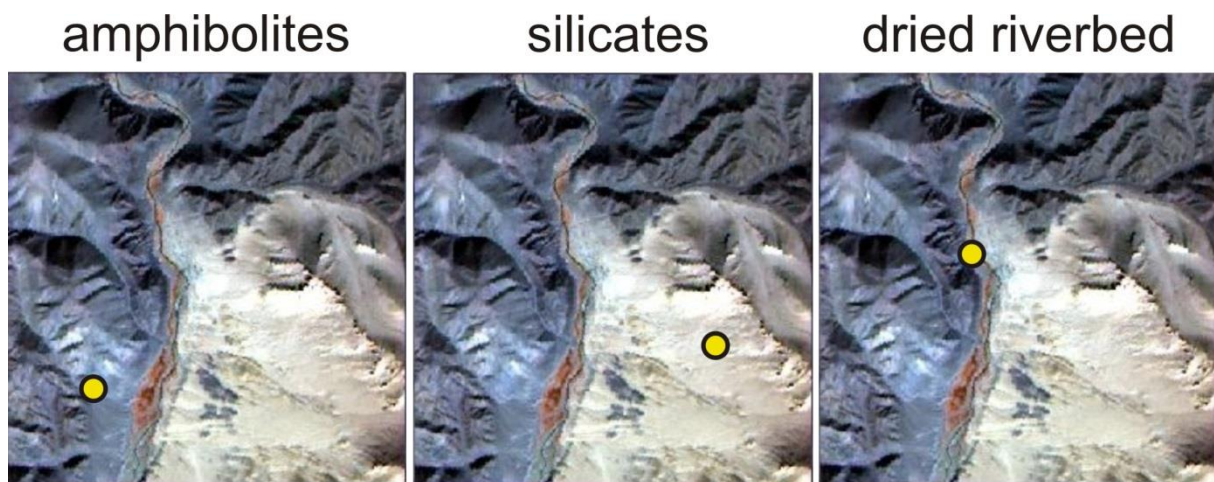


Figure 4. Localization of test spectra sites.



3. Results and discussion

Nine sharpened ASTER images were computed using nine different principle components substituted by the PAN band of WorldView-2. For each test site (amphibolitic rock, silicic rock and dried riverbed), spectra were collected from each tested sharpened image. Visual inspection of the compared spectra indicates that the first-component-picture features significant offset in all tested sites and has therefore the worst spectral accuracy from all tested principal components. Spectra comparison for amphibolitic rocks (Figure 5), silicates (Figure 6) and dried riverbed (Figure 7) shows significant improvement in the spectral performance when using the other components in the sharpening process. The best spectral performance for all the tested targets (the silicates, roof, vegetation and water) has been achieved when the 2nd PC was used in the sharpening process. On the other hand the ninth component contained mainly noise, thus should not be used in the sharpening process.

First preliminary results of our study show that using the 1st PC as a default doesn't have to be optimal when mineral/geological classification is requested. 1st PC approach is used mostly when visual interpretation is demanded, which is not the primary objective of approaches focusing on mineral spectral mapping. Using other than the 1st PC (e.g., PC2, PC3) we have spotted decrease of the visual interpretation quality of the resulting image, a spatial detail of the WorldView-2 image was suppressed, however still spatial content was higher than in original ASTER data (Figure 8). On the other hand, spectral accuracy of the resulting images was improved which would earn benefits for the geological mapping purposes. From that perspective, using the 2nd and 3rd PCs would be a solution for mineral spectral mapping when spectral accuracy is more important than the visual interpretation quality. Although PC 5 and higher featured also good spectral results, those components usually contain only noise and therefore those should not be taken into account. In the current testing, only visual inspection has been done. For the future work, several validation methods for spectral data are planned, for instance Spectral angle mapper (SAM), Spectral information divergence (SID), Average gradient, Global error in synthesis (ERGAS) or band-to-band correlation coefficient (CC).

Figure 5. Comparison of the original spectra of ASTER image and spectra of each pan sharpened image for the amphibolitic rocks.

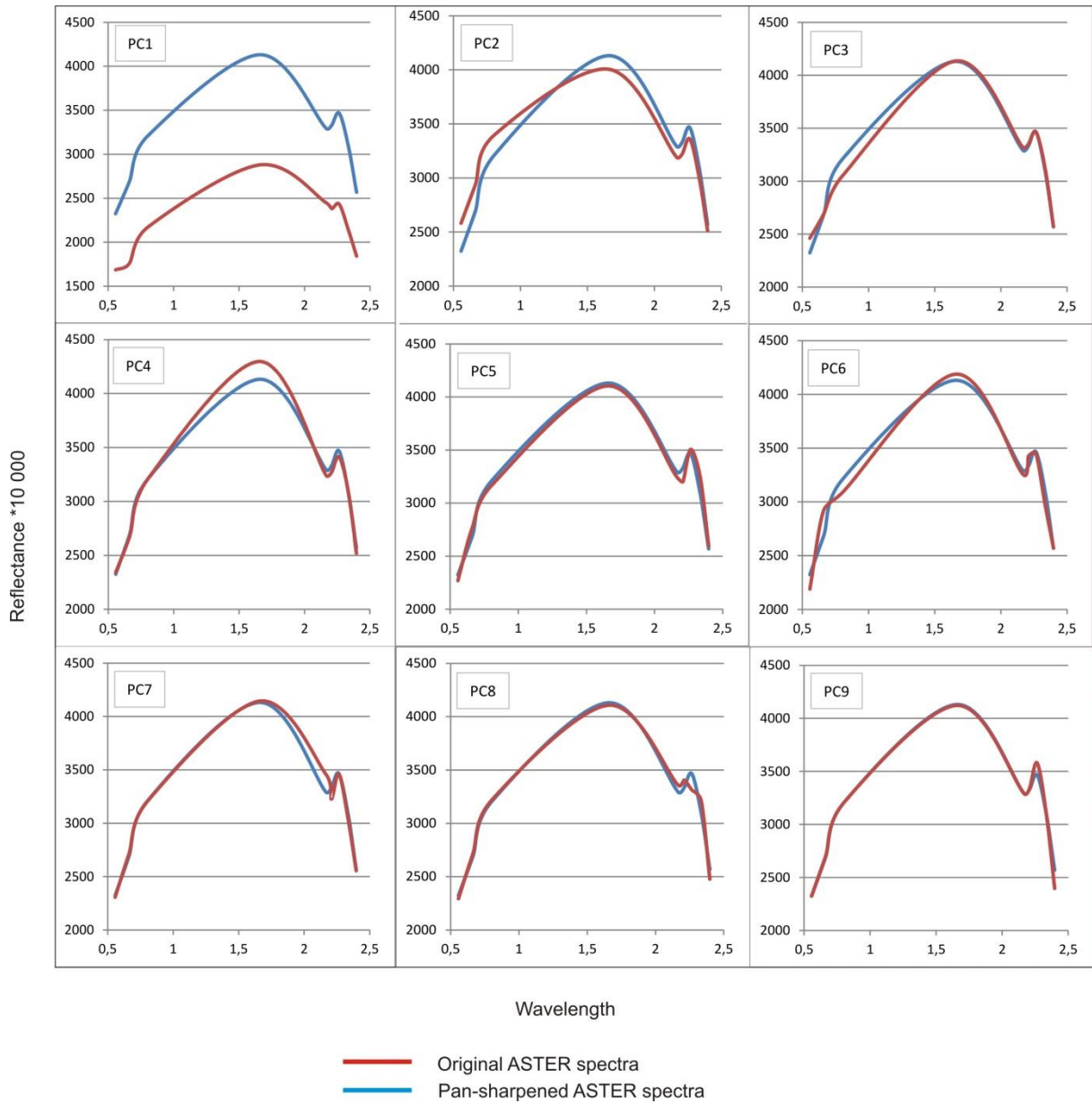


Figure 6. Comparison of the original spectra of ASTER image and spectra of each pan sharpened image for silicates.

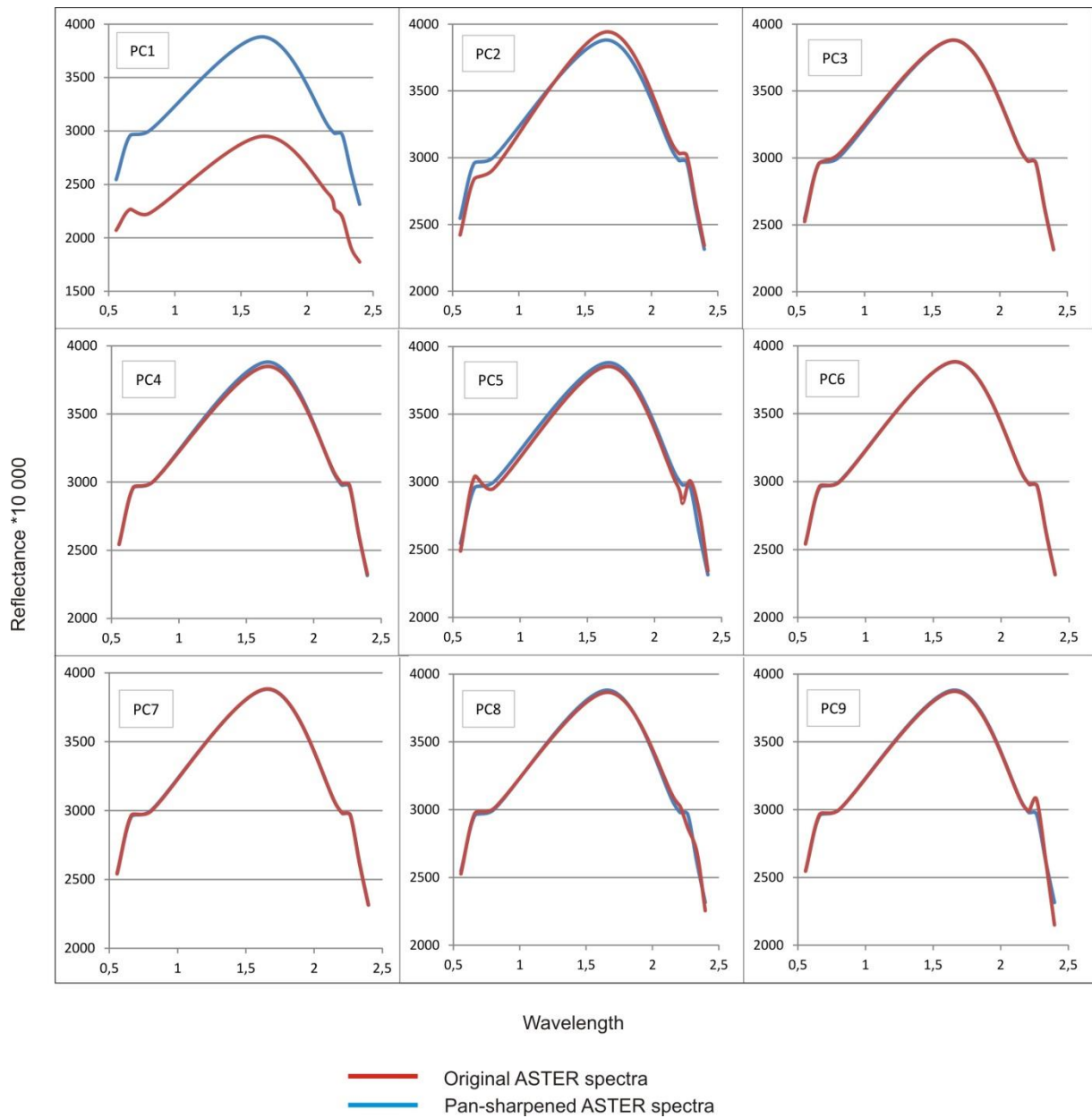


Figure 7. Comparison of the original spectra of ASTER image and spectra of each pan sharpened image for dried riverbed.

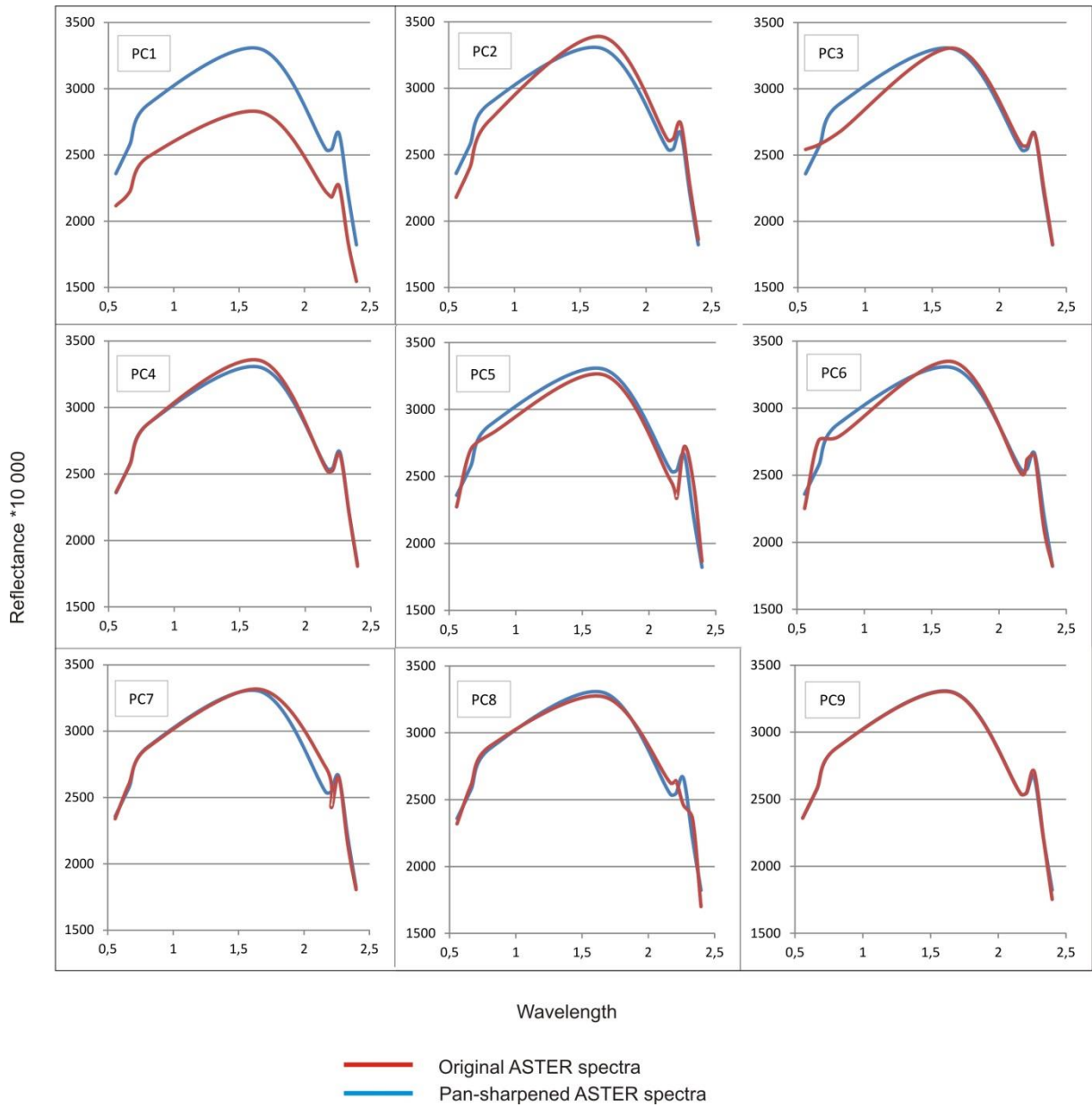
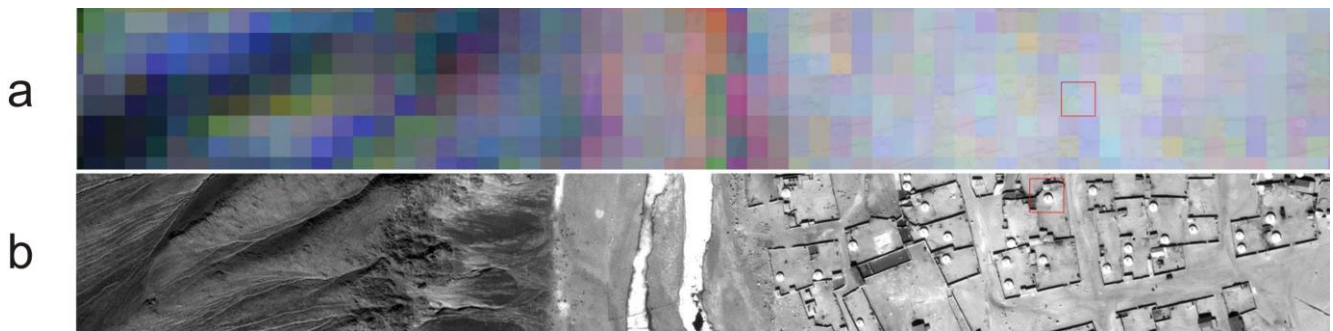


Figure 8. A comparison of a) pansharpened ASTER image using the second principal component (PC2) and the WorldView-2 PAN band and b) WorldView-2 PAN band.



4. Conclusions

In conclusion, a new approach for image sharpening via employing diverse Principle components was developed. Main scope of the work was to improve rather poor spectral performance of the PCA sharpening algorithm by using different than the first principal component. The new concept was tested using the ASTER image data and WorldView-2 PAN band. The best performance from the spectral point of view was observed in the image if the second or third component was used in the pansharpening process. The PCs 5-9 were not relevant for substitution due to a large amount of noise in the higher component numbers. Mineral maps resulting from classifications of the pansharpened ASTER data will be further tested and assessed using statistical methods.

Acknowledgments

This study contributed to the geological mapping project in the southwest Mongolia which has been conducted by the Czech geological survey. Project number: Cz-DA-RO-MN-2013-1-32220.

Author Contributions

Jan Jelének has done the processing work and prepared a draft version of the manuscript. Veronika Kopačková designed the study and added her contribution to the manuscript. Lucie Koucka helped with the IDL programing in ENVI.

Conflicts of Interest

The authors declare no conflict of interest.

References and Notes

1. Alparone, L.; Wald, L.; Chanussot, J.; Thomas, C.; Gamba, P.; Bruce, L.M. Comparison of Pansharpening Algorithms: Outcome of the 2006 GRS-S Data-Fusion Contest. *IEEE Transactions on geoscience and remote sensing*, 2007, 45, (3012-3021). doi: 10.1109/TGRS.2007.904923.

2. Chavez, P.S.; Kwarteng, A.Y. Extracting spectral contrast in Landsat Thematic Mapper image data using selective principal component analysis. *Photogrammetric Engineering and Remote Sensing*, 1989, 55, 3, (339-348)
3. Liu, J.G. Smoothing filter-based intensity modulation: A spectral preserve image fusion technique for improving spatial details Title of the chapter. *International Journal of Remote sensing*, 2000, 21, 18, (3461-3472). Doi: 10.1080/01431160110088772.
4. Salati, S.; Ruitenbeek, F. van; Meer, F. van der; Naimi, B.: Detection of Alteration Induced by Onshore Gas seeps from ASTER and WorldView-2 Data. *Remote Sensing*, 2014, 6, 4, (3188-3209), doi: 10.3390/rs6043188.
5. Shah, V.P.; Younan, N.H.; King R.L. An efficient Pan-sharpening method via a combined adaptive PCA approach and contourlets. *IEEE Transactions on geoscience and remote sensing*, 2008, 46, 5, (1323-1335), doi: 10.1109/TGRS.2008.916211.
6. Wang, Z.; Ziou, D.; Armenakis, C.; Deren, L.; Qingquan, L. A comparative analysis of image fusion methods. *IEEE Transactions on geoscience and remote sensing*, 2005, 43, 6, (1391-1402), doi: 10.1109/TGRS.2005.846874.
7. Yuhendra; Alimuddin, I.; Sumantyo, J.T.S.; Kuze, H. Assessment of pan-sharpening methods applied to image fusion of remotely sensed multi-band data. *International Journal of Applied Earth Observation and Geoinformation*, 2012, 18, (165-175), doi:10.1016/j.jag.2012.01.013. Available online: <http://www.sciencedirect.com/science/article/pii/S0303243412000153> (accessed on 19 May 2015).
8. Zhou, Z.M.; Ma, N.; Li, Y.X.; Yang, P.L.; Zhang, P.; Li, Y.Y. Variational PCA fusion for Pan-sharpening very high resolution imagery. *Science China Information Sciences*, 2014, 57, 11, (1-10), doi: 10.1007/s11432-014-5108-6.

© 2015 by the authors; licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution license (<http://creativecommons.org/licenses/by/4.0/>).