# MULTISPECTRAL CHANGE DETECTION AND INTERPRETATION USING SELECTIVE PRINCIPAL COMPONENTS AND THE TASSELED CAP TRANSFORMATION

Bill Pfaff
Utah State University

## Abstract

Temporal change is typically observed in all six reflective LANDSAT bands. The change is nominally six dimensional, yet these bands have significant correlation. The actual dimensionality of the change is typically three. Detection methods that do not produce at least three dimensions of change cannot make the most effective use of data.

The objective is to obtain a sequence of detection and interpretation techniques that detects change in all six bands, then presents essentially all of the detected change in three physically meaningful dimensions. Such a sequence is described herein. The detection is performed by Selective Principal Components Analysis, and the interpretation is performed by the Tasseled cap transformation.

This sequence extracts change information from all six bands, then displays essentially all (typically over 98%) of the detected change in three dimensions corresponding to soil, vegetation, and moisture. The technique is one that will consistently present the farmer or forester with complete and interpretable visualizations of temporal change.

## Introduction

Change *detection* in chromatic multispectral images is most effective when every available spectral band is processed. Change *interpretation* in these images becomes more effective when the change information is presented in as many physically meaningful dimensions as possible since change rarely occurs along a single axis.

Some change detection methods do an excellent job of processing all the available information, but the detected change is presented in dimensions that make the nature of the change difficult to interpret. The traditional method of Merged Principal Components Analysis[1] presents change information in an often intractable blend of spectral and temporal dimensions. It is this confusion of dimensionality that makes Merged Principal Components Analysis a less-than-ideal change detection method.

Other methods present the detected change in physically meaningful dimensions, but the *number* of dimensions available for interpretation is less than the number of dimensions along which the change transpired. Detection methods that preserve spectral dimensionality are usually followed by interpretation methods using only one dimension, typically band ratios or vegetation indices.

The ideal detection-interpretation sequence, therefore, captures change information from all spectral bands then presents the change information in as many dimensions (colors) as necessary to completely describe the change. In other words, the sequence combines *access* to all dimensions of change with the ability to *display* all dimensions of change.

The data used in this paper are from the six reflective LANDSAT Thematic Mapper bands. Interband correlation provides the opportunity to display essentially all of the nominally six dimensional detected change in only three dimensions. Assigning these three dimensions to the three primary colors allows the change to be observed in a single false color composite. The three dimensions of displayed change must correspond to the physical nature of the change, otherwise the detected change is difficult to interpret.

The LANDSAT data, therefore, requires detection of change in six bands and the presentation of the detected change in three physically meaningful false colors. The sequence of the Selective Principal Component[2] and Tasseled Cap[3,4] transformations meets this requirement. This sequence combines the decorrelation capability of Principal Components

Analysis with the interpretation and reduction-in-dimensionality capability of the Tasseled Cap.

Algebraic Methods of Change Detection

Simple image differencing is sensitive to uniform change caused by sun angle, atmospheric haze, water vapor, etc. This sensitivity is reduced by normalizing the difference values. The two differencing techniques are

$$SD = (L - E) + 127.5 \qquad (1)$$

$$ND = \left(\frac{L-E}{L+E}\right) \bullet \left(\overline{L} + \overline{E}\right) + 127.5 \qquad (2)$$

where $E$ is the color value from the earlier image, $L$ is the color value from the later image, $\overline{E}$ and $\overline{L}$ are scaling constants, 127.5 is a level shifting constant, $SD$ is the simple difference, and $ND$ is the normalized difference.

Images of band-pair pixel ratios can be used to evaluate change, and are somewhat insensitive to uniform change.

$$R = \left(\frac{L}{E}\right) \bullet \overline{E} \qquad (3)$$

All algebraic methods present the detected change in the dimensions of the original spectral variables. However, the nonlinear methods, ratioing and normalized differencing, distort the original variables and this could effect interpretation. The linear method, simple differencing, does not distort the original variables; however, it is sensitive to uniform change.

Rotational Methods of Change Detection

Merged Principal Components Analysis

Merged Principal Components Analysis is simply obtaining the Principal Components of a stack of multispectral images. The change information is, however, distributed throughout all twelve Principal Components. Merged Principal Components Analysis transforms the original spectral variables into variables that combine and confuse spectral and temporal dimensions, which makes the interpretation of detected change unnecessarily difficult.

Selective Principal Components Analysis

This method exploits the decorrelation capability of Principal Components Analysis, yet preserves the original dimensionality of the data. Temporal correlation begins with the creation of $n$ two-band images. Each band in these two-band images has the same spectral dimension but was recorded at different times.

A Principal Components Analysis of this two-band image will produce two uncorrelated components. The first component generally provides a pantemporal description of static features in the scene. The second component, being uncorrelated with the first, highlights the scene features that changed between the two image dates. These components describe the data in terms of a single spectral band. The confusion of dimensions normally produced by Merged Principal Components Analysis does not occur with Selective Principal Components Analysis.

Repeating the process on all six LANDSAT bands produces twelve components. Six will depict static features, and are referred to as the *Static* components. The other six will depict change features, and are referred to as the *Change* components. The six *Change* components can be combined into a six-band, temporally decorrelated image.

An important advantage of using Selective Principal Components Analysis for change detection is that it ignores uniform change. This is because the data is decorrelated rather than differenced. Because the *Static* and *Change* components are expressed in the original spectral dimensions, the Tasseled Cap transformation can be used to interpret these components.

It has been shown[5] that in the two dimensional case Principal Components Analysis[6] must be based on the covariance matrix rather than the correlation matrix. Basing it on the correlation matrix normalizes both axes and the *Static* component will invariably be the 45° diagonal, reducing the algorithm to simple differencing.

The Tasseled Cap Transformation

The Tasseled Cap[2,3] transformation projects the six-band data onto a set of vectors that correspond to parameters of interest to agronomists. The first

Tasseled Cap component known as the *Soil Brightness* component, henceforth abbreviated to the *Brightness* component. The second component measures green biomass, and is known as the *Greenness* component. The third component measures surface moisture, and is referred to as the *Wetness* component.

In a typical false color composite of an agricultural scene, *Brightness* is given the color blue, *Greenness* is green, and *Wetness* is red. Spray from a central pivot irrigation system has a strong *Wetness* component and appears in the false color composite as a red colored plume. Dry, green vegetation appears green and newly watered vegetation appears yellow because of its strong *Greenness* and *Wetness* components. Dry, bare soil appears blue because of its "*Brightness*".

## Applying the Detection-Interpretation Sequence

This sequence is described graphically in Fig. 1. Two images of an agricultural scene in southeastern Idaho[7] were acquired for this evaluation. The images are from July 24, and August 9, 1992.

Selective Principal Components Analysis was applied to these images and the *Static* and *Change* components of each spectral band can be seen in Fig. 2.. These one dimensional *Static* and *Change* components were projected into Tasseled Cap space forming the three dimensional *Static* and *Change* components shown in Figs. 3 and 4. For reference, the original images were also projected into Tasseled Cap space as shown in Figs. 4 and 5.

Note the similarity between the *Static* component in Fig. 3 and the original image data in Figs. 5 and 6. The *Static* component contains information that is common to both dates. The *Change* component in Fig. 4 reveals that there was an increase in bare soil during the 16-day interval. The blue *Brightness* cluster was created by harvesting and the attendant exposure of soil. There was also a mild increase in *Greenness* in other areas.

These scatter plots are presented solely to describe the process. The transformed image data is typically presented in the familiar form of false color composite images, which are used to reveal the location as well as the nature of the change.

There are a couple of unusual situations in which unmodified Selective Principal Components Analysis will fail to produce satisfactory results. These situations and the necessary modifications are described elsewhere[5].

## Conclusions

Selective Principal Components Analysis is an effective, linear, means of discriminating between features that did indeed change, and features that only appear to have changed because of external effects. Linearity is important because many scenes will force a nonlinear, ratiometric algorithm to produce artifacts that both mimic and obscure actual change.

Selective Principal Components Analysis presents the detected change using the original spectral bands. A related method, Merged Principal Components Analysis, mixes the static and change information in an intractable blend of spectral and temporal dimensions.

The Tasseled Cap transformation processes all six bands of detected change, then presents over 98% of the detected change in false colors representing surface moisture, vegetative biomass, and soil brightness. Other interpretation algorithms such as vegetation indices process fewer dimensions of change and present the detected change in only one dimension.

## Acknowledgments

The author wishes to thank the NASA John C. Stennis Space Center's CRSP under Bruce Davis, Hugh Carr, and Cliff Holle. Thanks also must go to the Rocky Mountain NASA Space Grant Consortium under Julius Dasch, Doran Baker, and Frank Redd, for the fellowship supporting the graduate research.

Ralph Oborn of J. R. Simplot Co. provided insights in, and enthusiasm for, remote sensing and agronomy. Doran Baker, provided vision and encouragement. Thanks also must go to Allan Falconer, Douglas Ramsey, and Colin Homer of the USU Geography and Earth Resources Department.

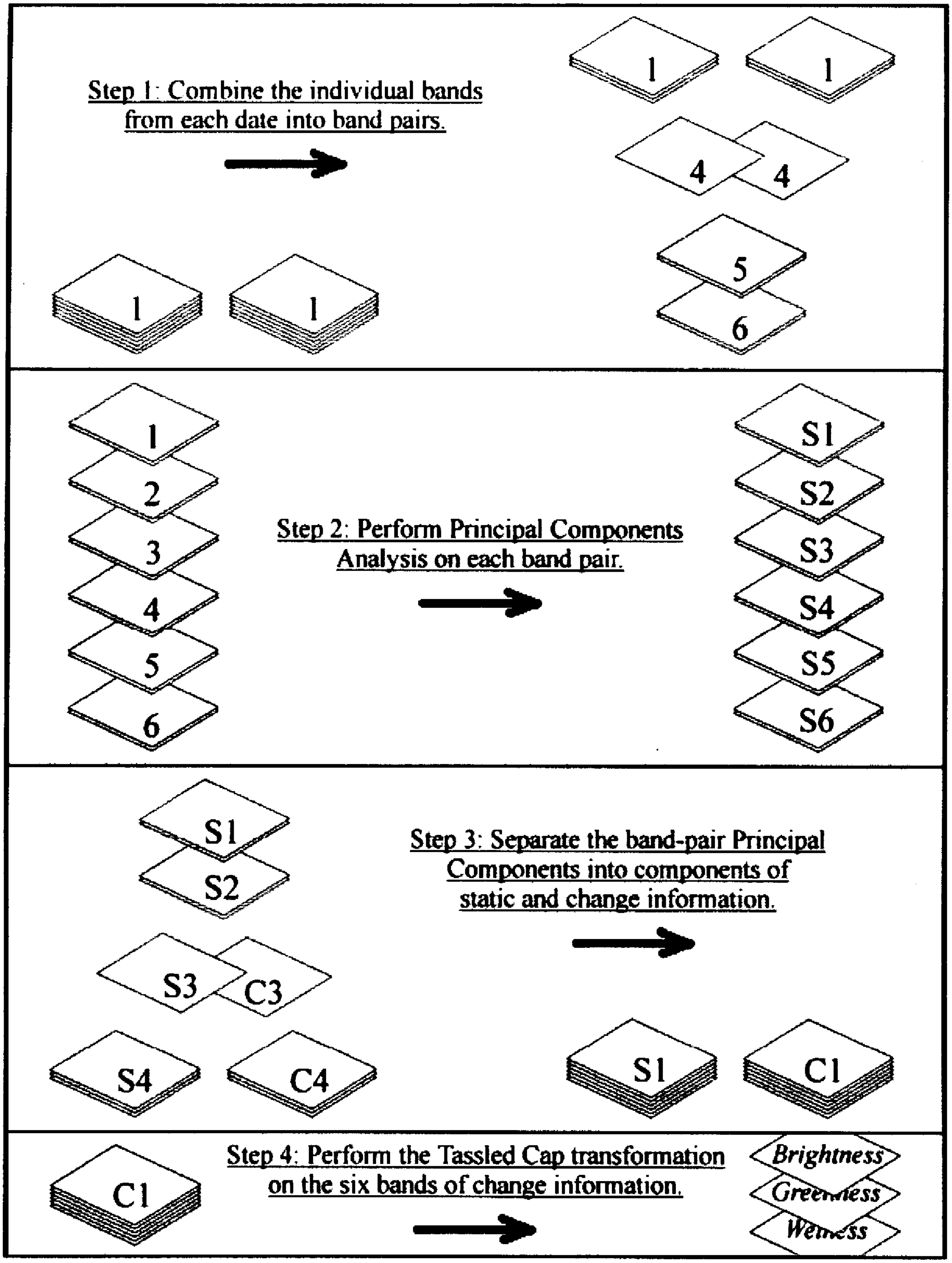


Figure 1: The sequence of Selective Principal Components Analysis and the Tassled Cap transformation.

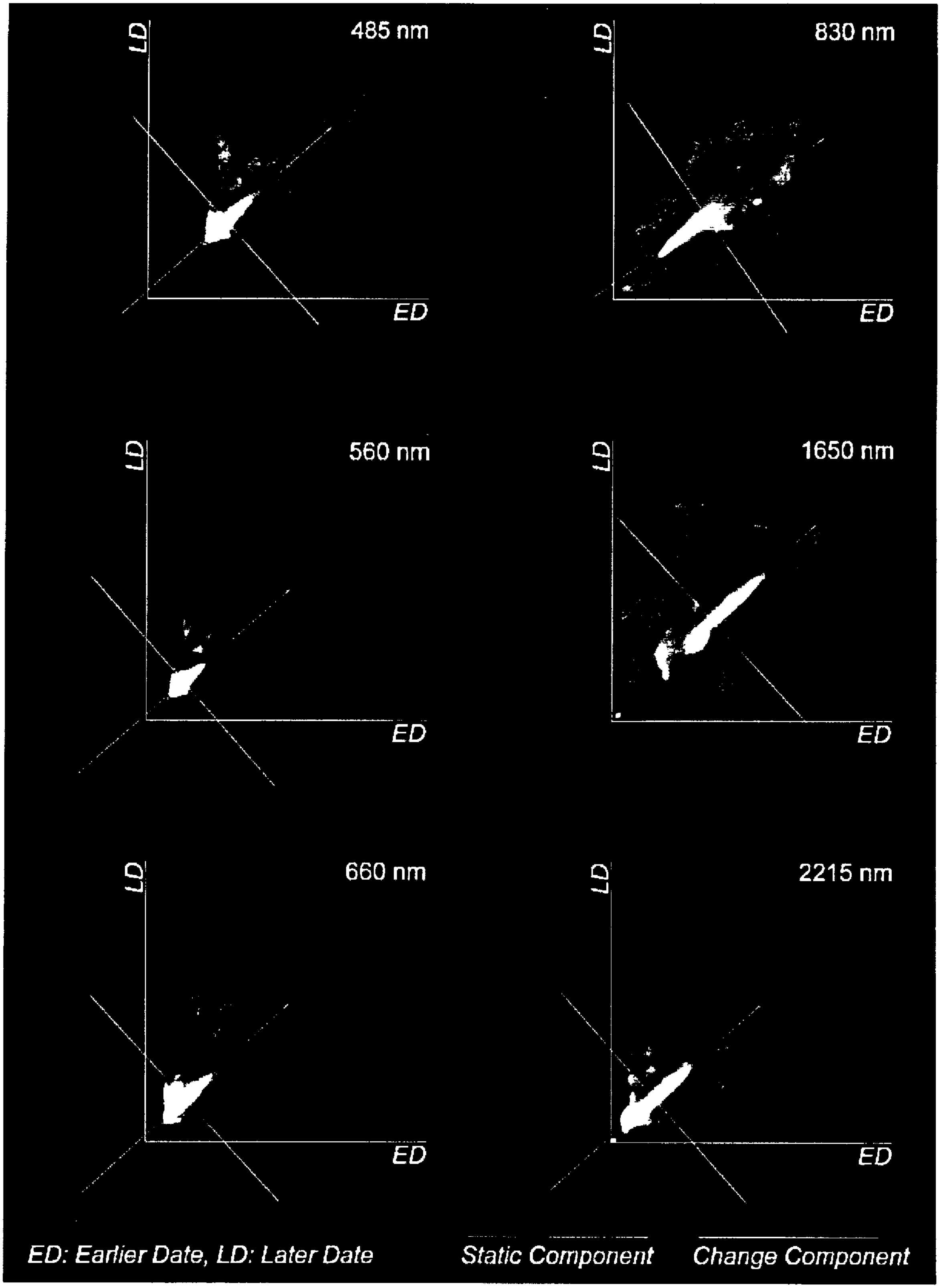


Fig. 2. ***Static*** **and** ***Change*** **components of the** ***July 24:August 9*** **image pair.**

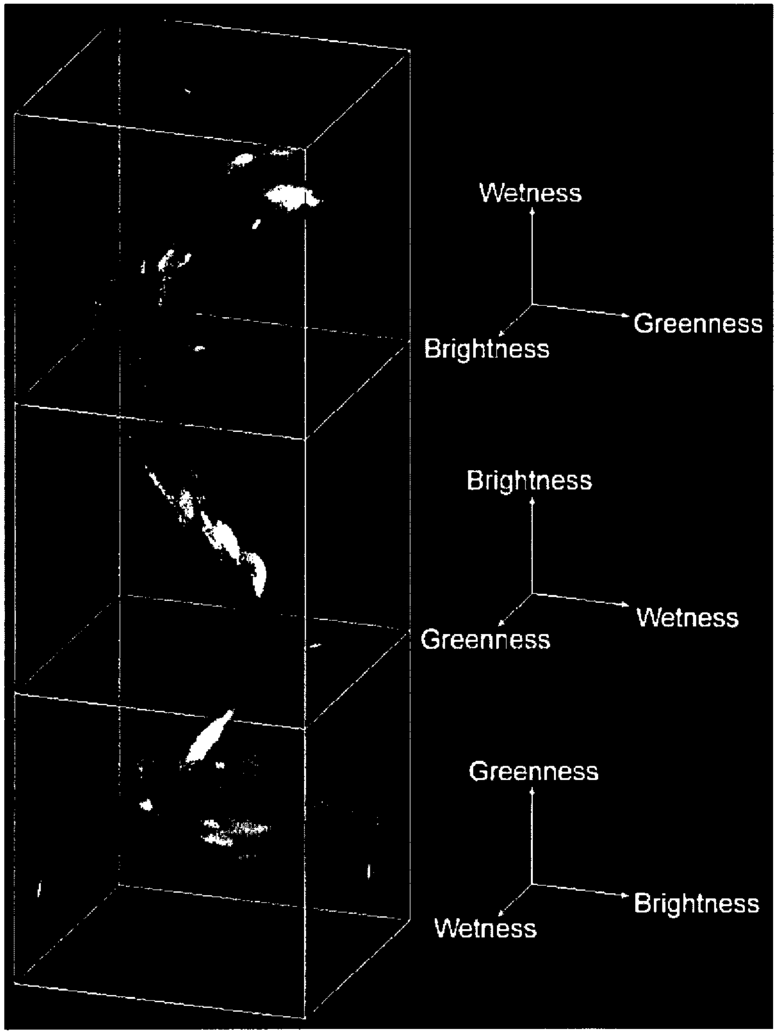


Fig. 3. Scatter plot of low order Tasseled Cap components of the *Static* components of the *July 24:August 9* image pair. These components contain 98.1% of *Static* information.

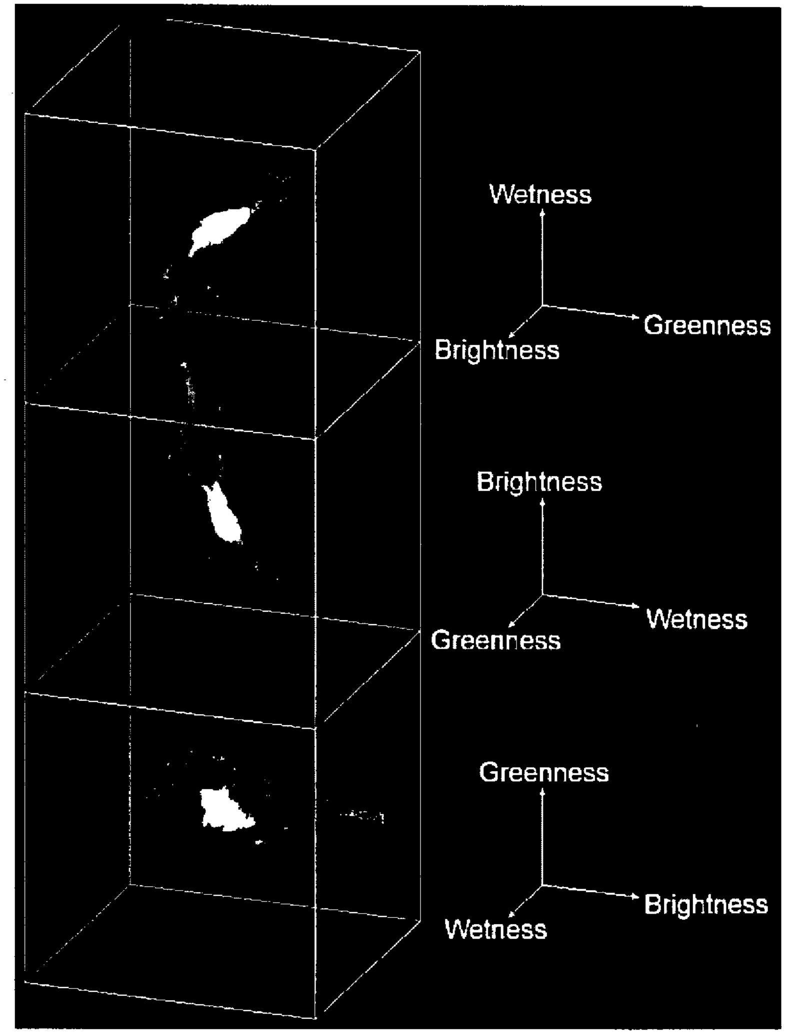


Fig. 4. Scatter plot of low order Tasseled Cap components of the *Change* component of the *July 24:August 9* image pair. These components contain 98.8% of detected change.

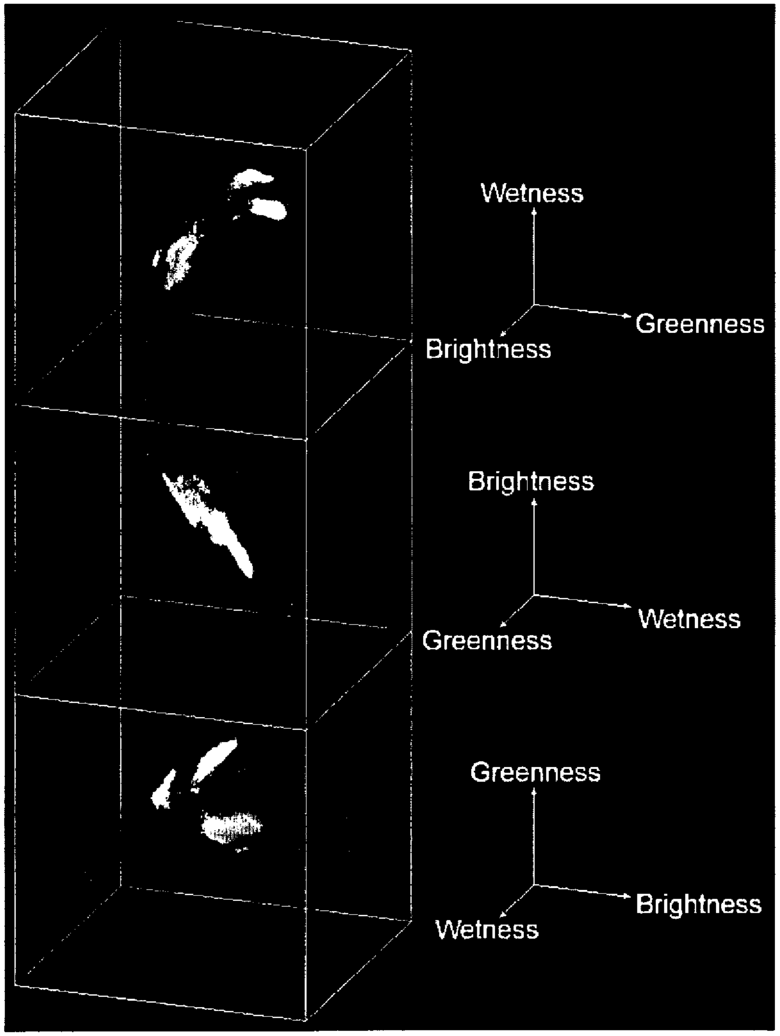


Fig. 5. Scatter plot of low order Tasseled Cap components of the July 24 image. The Tasseled Cap components contain 98.9% of scene information.

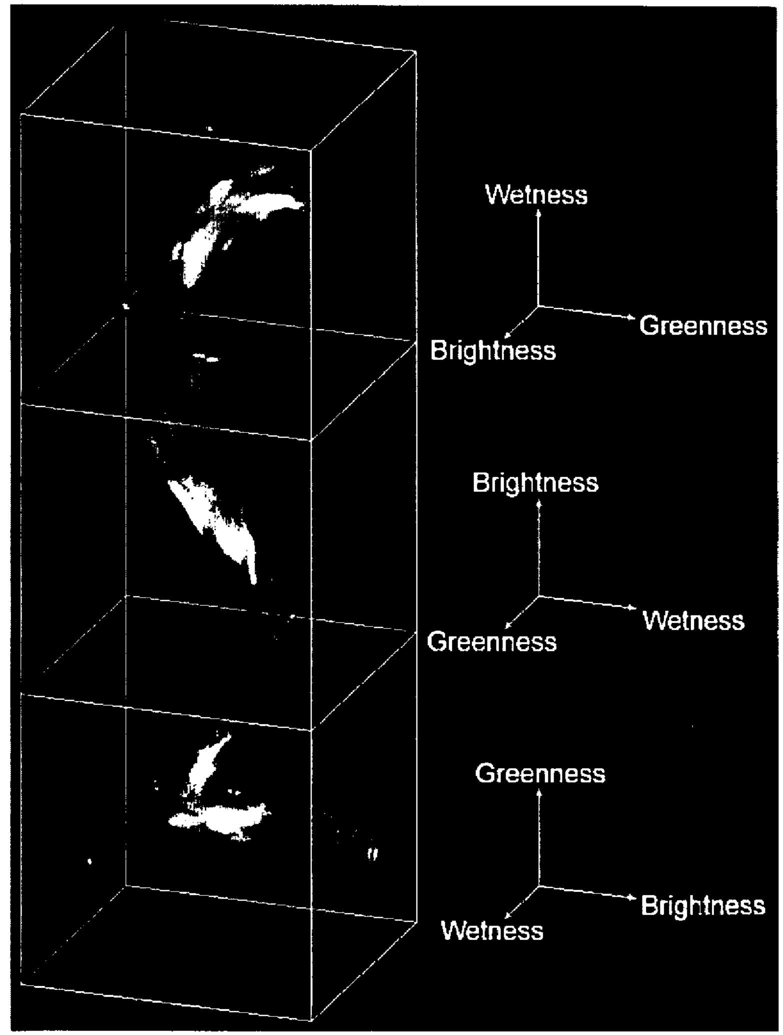


Fig. 6. Scatter plot of the low order Tasseled Cap components of the August 9 image. The Tasseled Cap components contain 98.6% of scene information.

## REFERENCES


1 G. F. Byrne, P. F. Crapper, and K. K. Mayo, "Monitoring land-cover change by principal components analysis of multitemporal Landsat data," *Remote Sensing of Environment*, vol. 10, pp. 175-184, 1980.

2 P. S. Chavez and A. Y. Kwarteng, "Extracting spectral contrast in Landsat thematic mapper data using selective principal components analysis," *Photogrammetric Engineering and Remote Sensing*, vol. 55, no. 3, pp. 339-348, 1989.

3 R. J. Kauth and G. S. Thomas, "The tasseled cap-a graphic description of the spectral-temporal development of agricultural crops as seen by Landsat," in *Proc. Symp. Machine Processing of Remotely Sensed Data*, West Lafayette, IN, 1976, pp. 4b:41-4b:51.

4 E. P. Crist and R. C. Cicone, "A physically-based transformation of thematic mapper data-the TM tasseled cap," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 22, no. 3, pp. 256-263, 1984.

5 W. P. Pfaff, "Multispectral change detection and interpretation using selective principal components and the tasseled cap transformation," MS thesis, USU, 1998.

6 L. Eklundh and A. Singh, "Comparative analysis of standardized and unstandardized principal components analysis in remote sensing," *International Journal of Remote Sensing*, vol. 14, no. 7, pp. 1359-1370, 1993.

7 R. A. Oborn and W. P. Pfaff, "Remote sensing and GIS applied to site-specific agriculture," NASA Stennis Space Center, MS, 1998.