EXELIS

Visual Information Solutions

# ENVI Classic Tutorial: Spectral Angle Mapper (SAM) and Spectral Information Divergence (SID) Classification

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# Spectral Angle Mapper (SAM) and Spectral Information Divergence (SID) Classification

This tutorial provides an introduction to the Spectral Angle Mapper (SAM) and Spectral Information Divergence (SID) supervised classification methods and compares the results produced by each method on the same image.

## Files Used in this Tutorial

Download data files from the Exelis website.

| File | Description |
|---|---|
| `cup95eff.int` | AVIRIS atmospherically corrected reflectance data (50-band subset) |
| `cup95eff.hdr` | ENVI header for above |
| `jpl1.sli` | Spectral library |
| `jpl1.hdr` | Header file for above |

## Background

SAM and SID are both spectral measures. SAM is a deterministic method that looks for an exact pixel match and weights the differences the same. SID is a probabilistic method that allows for variations in pixel measurements, where probability is measured from zero to a user-defined threshold.

### References

SAM: Kruse, F. A., A. B. Lefkoff, J. B. Boardman, K. B. Heidebrecht, A. T. Shapiro, P. J. Barloon, and A. F. H. Goetz, 1993, “The Spectral Image Processing System (SIPS) - Interactive Visualization and Analysis of Imaging spectrometer Data.” Remote Sensing of the Environment, v. 44, pp. 145-163.

SID: H. Du, C.-I. Chang, H. Ren, F.M. D’Amico, J. O. Jensen, J., 2004, “New Hyperspectral Discrimination Measure for Spectral Characterization.” Optical Engineering, v. 43, No. 8, pp. 1777-1786.

# Applying SAM Classification

SAM is a physically-based spectral classification that uses an n-dimensional angle to match pixels to reference spectra. The algorithm determines the spectral similarity between two spectra by calculating the angle between the spectra and treating them as vectors in a space with dimensionality equal to the number of bands. When used on calibrated reflectance data, this technique is relatively insensitive to illumination and albedo effects. Endmember spectra used by SAM can come from ASCII files or spectral libraries, or you can extract them directly from an image (as ROI average or Z-profile spectra). In this tutorial, you will use a spectral library.

SAM compares the angle between the endmember spectrum vector and each pixel spectrum vector in n-D space. Smaller angles represent closer matches to the reference spectrum. Pixels further away than the specified maximum angle threshold in radians are not classified.

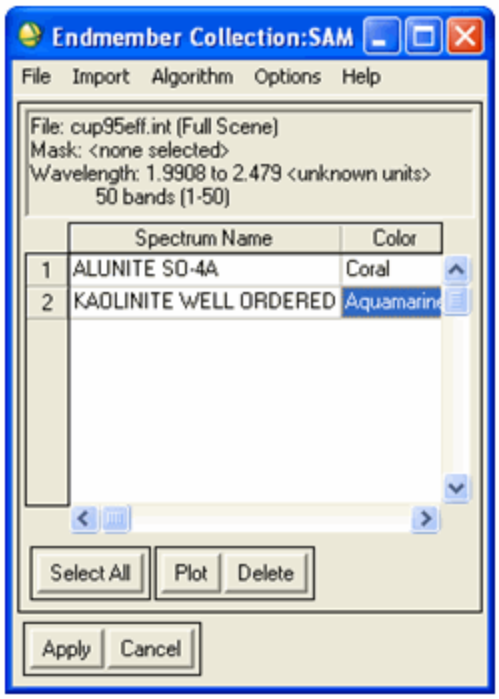
## Selecting the Files

1. From the ENVI® Classic main menu bar, select **Classification > Supervised > Spectral Angle Mapper**. The Classification Input File dialog appears.
2. Click **Open** and select **New File**. The Please Select New File dialog appears.
3. Select `cup95eff.int` and click **Open**, followed by **OK**. The Endmember Collection:SAM dialog appears.

## Collecting Endmember Spectra

1. From the Endmember Collection:SAM dialog menu bar, select **Import > from Spectral Library file**. The Spectral Input File dialog appears.
2. Click **Open** and select **Spectral Library**. The Please Select New File dialog appears.
3. Select `jpl1.sli` and click **Open**, followed by **OK**. The Input Spectral Library dialog appears.
4. Use **Ctrl+click** to select the following input spectra:
   - **ALUNITE SO-4A**
   - **KAOLINITE WELL ORDERED PS-1A**

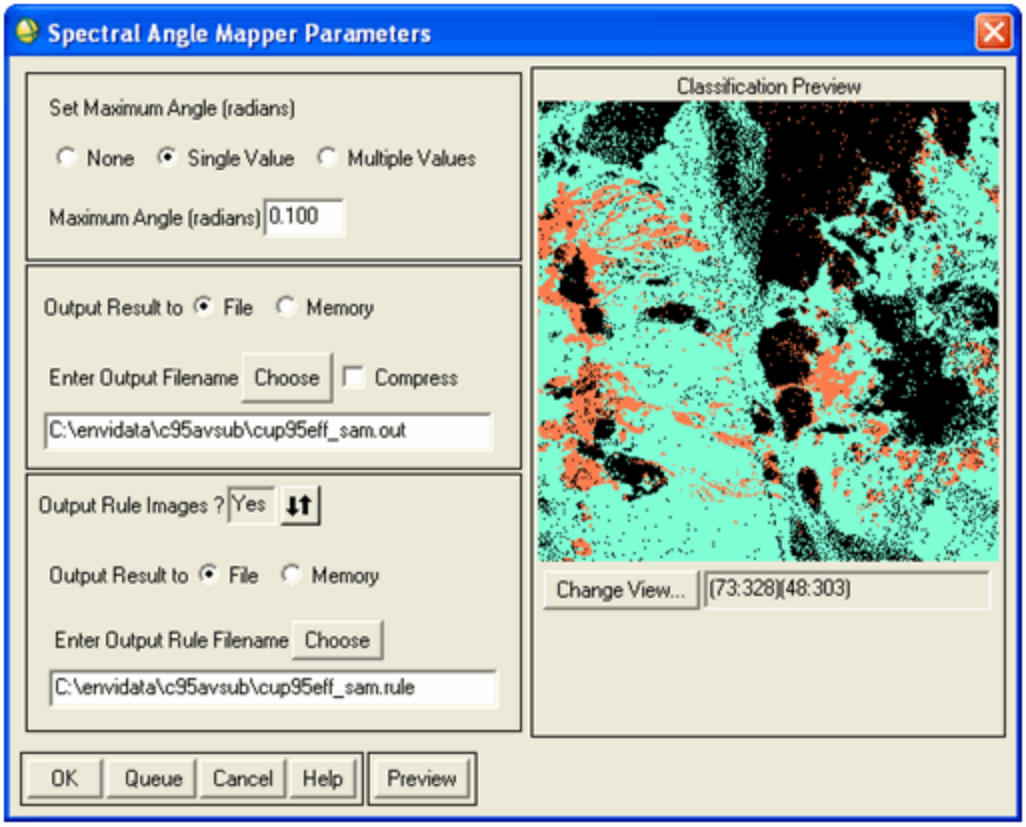
   Click **OK**. The selections are added to the Endmember Collection:SAM dialog.
5. Right-click in each **Color** cell and change the color for each spectrum to what is shown in the dialog example below.




6. Click **Apply**. The Spectral Angle Mapper Parameters dialog appears.

## Setting SAM Parameters

1. Use the default thresholding option **Single Value** and keep the default setting of **0.1** for **Maximum Angle (radians)**. This parameter defines the maximum acceptable angle between the endmember spectrum vector and the pixel vector (in # of bands dimensional space). SAM will not classify pixels with an angle larger than this value.
2. Output the classification to a **File** and enter the filename `cup95eff_sam.out`.
3. Set the **Output Rule Images?** toggle button to **Yes** and enter the filename `cup95eff_sam.rule`.
4. Click **Preview** to see a 256 x 256 spatial subset from the center of the output classification image. Your Spectral Angle Mapper Parameters dialog and preview window should look similar to this:




(You can optionally change the parameters if needed and click Preview again to update the display.)

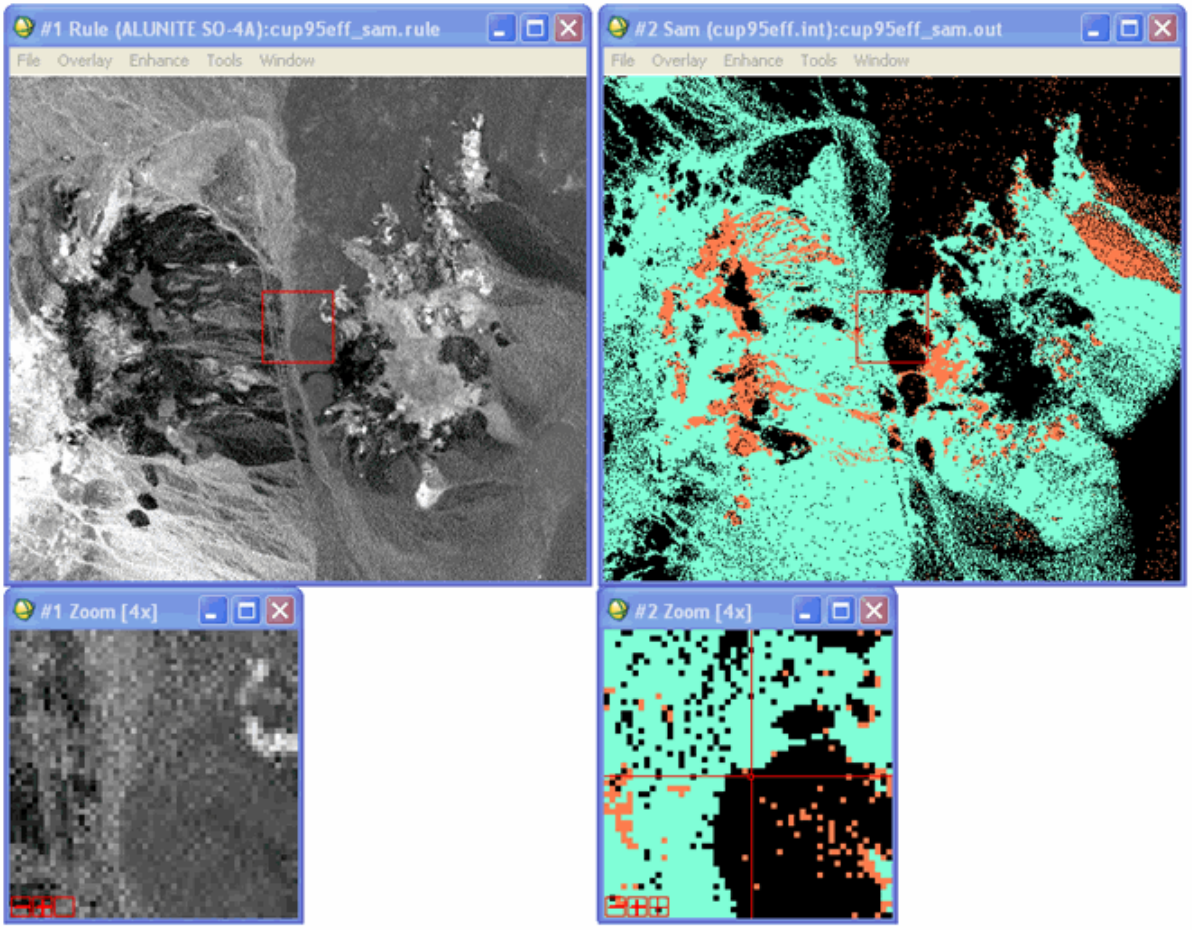
5. Click **OK**. ENVI Classic adds the `cup95eff_sam.out` and `cup95eff_sam.rule` files to the Available Bands List.


The `cup95eff_sam.out` file is the classified image. The `cup95eff_sam.rule` file is the rule file, which contains one image for Alunite and one image for Kaolinite.

## SAM Output

In the Available Bands List, right-click **Rule (ALUNITE SO-4A)** under `cup95eff_sam.rule`, then select **Load Band to New Display**. Right-click on **Sam (cup95eff.int)**, then select **Load Band to New Display**. This opens Display groups loaded with the SAM rule image for Alunite (below left) and the SAM classification image (below right).

In the SAM Alunite rule image, the pixel values of the rule image represent the spectral angle in radians from the reference spectrum for each class. Lower spectral angles represent better matches to the endmember spectra. Areas that satisfied the selected radian threshold criteria were carried over as classified areas into the classified image. In the example below, the SAM classification image shows areas classified as Alunite (coral) and Kaolinite (aquamarine). Unclassified areas are black.




Note: If you find it more intuitive to show the best matches to the endmember spectra as brighter pixel values (as opposed to darker values, which is the default with SAM), follow these steps: From the #1 display group menu bar (Rule…), select **Tools > Color Mapping > Control RGB Image Planes**. In the RGB Channels dialog, click all three **Normal** toggle buttons to select **Inverse**. From the RGB Channels dialog menu bar, select **Options > Apply**.

Next, you will run the SID classification on the `cup95eff.int` file.

# Applying SID Classification

SID is a spectral classification method that uses a divergence measure to match pixels to reference spectra. The smaller the divergence, the more likely the pixels are similar. Pixels with a measurement greater than the specified maximum divergence threshold are not classified. Endmember spectra used by SID can come from ASCII files or spectral libraries, or you can extract them directly from an image (as ROI average or Z-profile spectra). In this tutorial, you will use a spectral library.

## Selecting the Files

1. From the ENVI Classic main menu bar, select **Classification > Supervised > Spectral Information Divergence**. The Classification Input File dialog appears.
2. Select the `cup95eff.int` file that was previously opened for the SAM classification, then click **OK**. The Endmember Collection:SID dialog appears.

## Collecting Endmember Spectra

1. From the Endmember Collection:SID dialog menu bar, select **Import > from Spectral Library file**. The Spectral Input File dialog appears.
2. Select `jpl1.sli`, then click **OK**. The Input Spectral Library dialog appears.
3. Use **Ctrl+click** to select the following input spectra:

   **ALUNITE SO-4A**

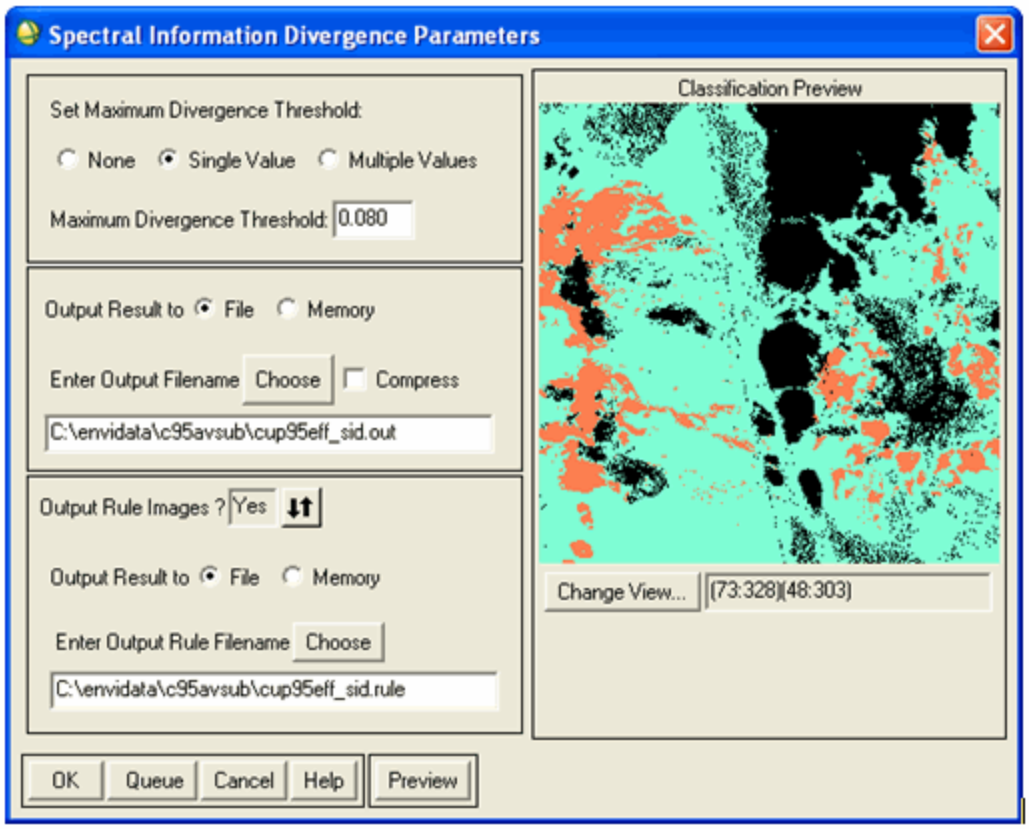
   **KAOLINITE WELL ORDERED PS-1A**

   Click **OK**. The selections are added to the Endmember Collection:SID dialog.
4. Right-click in each **Color** cell and change the color for each spectrum to what is shown in the dialog example on the right.
5. Click **Apply**. The Spectral Information Divergence Parameters dialog appears.

## Setting SID Parameters

1. Use the default thresholding option **Single Value** and change the **Maximum Divergence Threshold** to **.08**. This is the minimum allowable variation between the endmember spectrum vector and the pixel vector. The default value is .05, but it can vary substantially given the nature of the similarity measure. A threshold that discriminates well for one pair of spectral vectors may be either too sensitive, or not sensitive enough, for another pair due to the similar/dissimilar nature of their probability distributions. For the purpose of this exercise, a setting of .08 provides a SID result that is similar to the one produced by SAM.
2. Output the classification to a **File** and enter the filename `cup95eff_sid.out`.
3. Set the **Output Rule Images?** toggle button to **Yes** and enter the filename `cup95eff_sid.rule`.

4. Click **Preview** to see a 256 x 256 spatial subset from the center of the output classification image. Your Spectral Information Divergence Parameters dialog and preview window should look similar to this:




(You can optionally change the parameters if needed and click Preview again to update the display.)

5. Click **OK**. ENVI Classic adds the `cup95eff_sid.out` and `cup95eff_sid.rule` files to the Available Bands List.

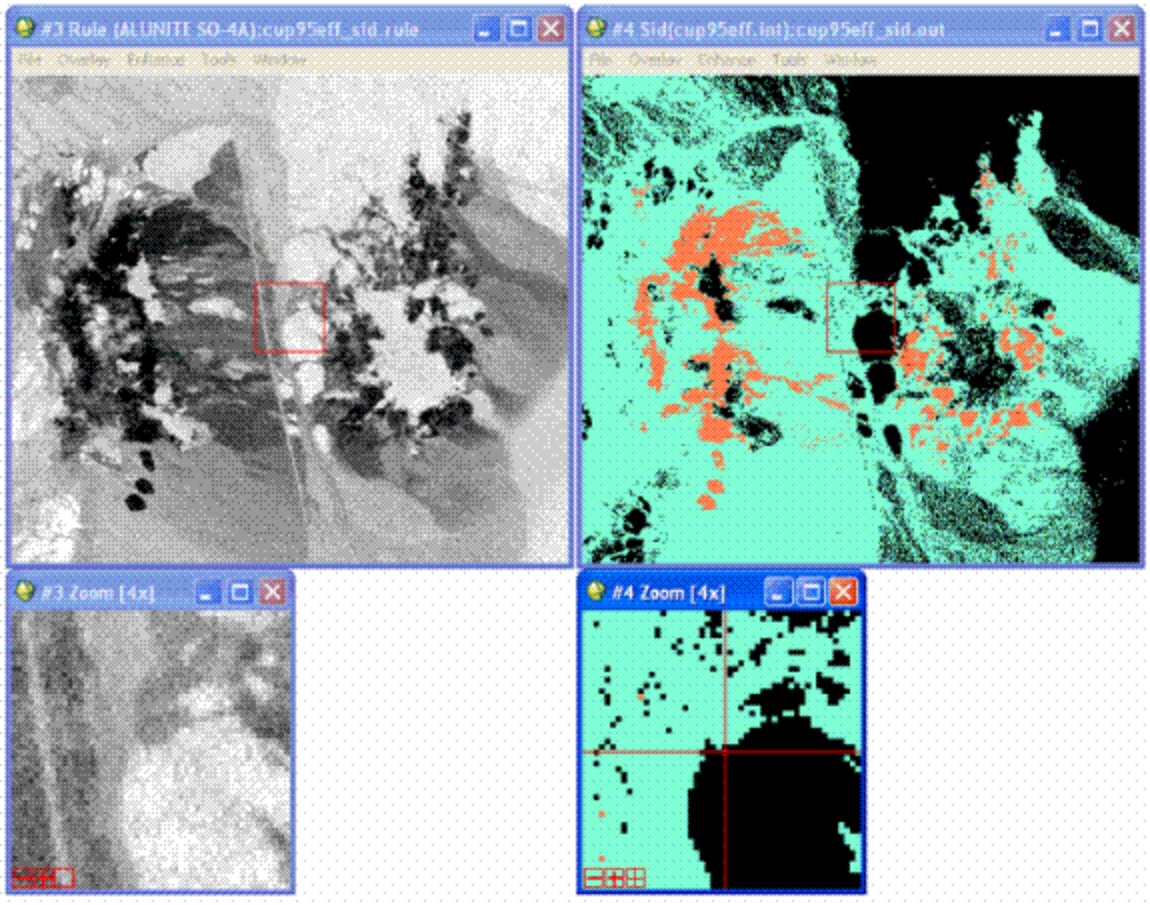
   The `cup95eff_sid.out` file is the classified image. The `cup95eff_sid.rule` is the rule file, which contains one image for Alunite and one image for Kaolinite.

## SID Output

In the Available Bands List, right-click on **Rule (ALUNITE SO-4A)** under `cup95eff_sid.rule`, then select **Load Band to New Display**. Right-click on **Sid (cup95eff.int)**, then select **Load Band to New Display**. This opens Display groups loaded with the SID rule image for Alunite (below left) and the SID classification image (below right).

In the SID Alunite rule image, the pixel values of the rule image represent the SID value (the output of the equation that defines SID for a pair of spectral vectors). Lower spectral divergence measures

represent better matches to the endmember spectra. Areas that satisfied the maximum divergence threshold criteria were carried over as classified areas into the classified image. In the example below, the SID classification image shows areas classified as Alunite (coral) and Kaolinite (aquamarine). Unclassified areas are black.

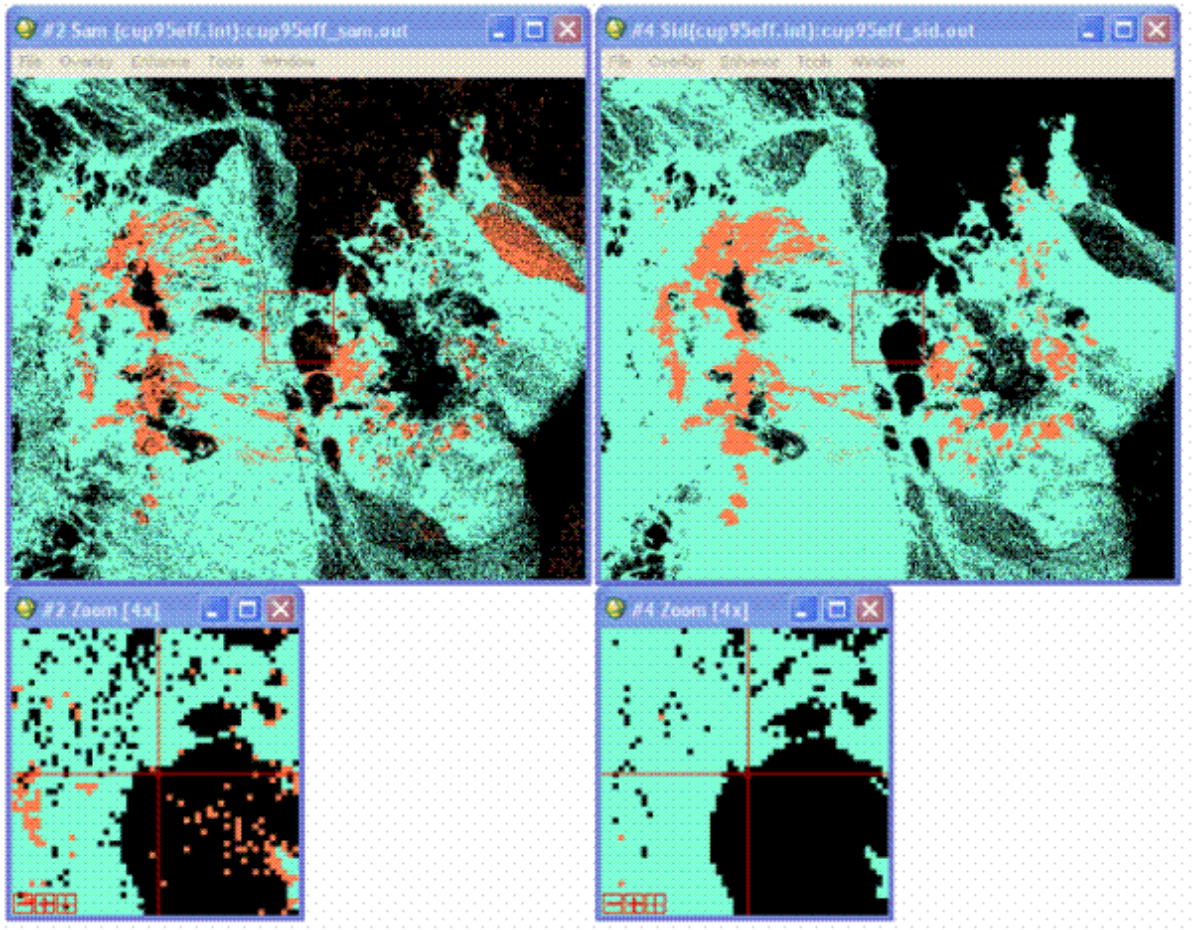



Note: If you find it more intuitive to show the best matches to the endmember spectra as brighter pixel values (as opposed to darker values, which is the default with SID), follow these steps: From the #1 display group menu bar (Rule), select **Tools > Color Mapping > Control RGB Image Planes**. In the RGB Channels dialog, click all three **Normal** toggle buttons to select **Inverse**. From the RGB Channels dialog menu bar, select **Options > Apply**.

Next, you will examine the SAM and SID classification images side-by-side.

## Comparing SAM and SID Output

When you view the SAM (right) and SID (left) classification images side-by-side, you see that the results are similar, although the SAM output appears to have more noise.




Next, you will examine three regions of the original image and compare the spectral profile in the original image to the known Alunite SO-4A spectral signature from the Spectral Library. To prepare for this, do the following:

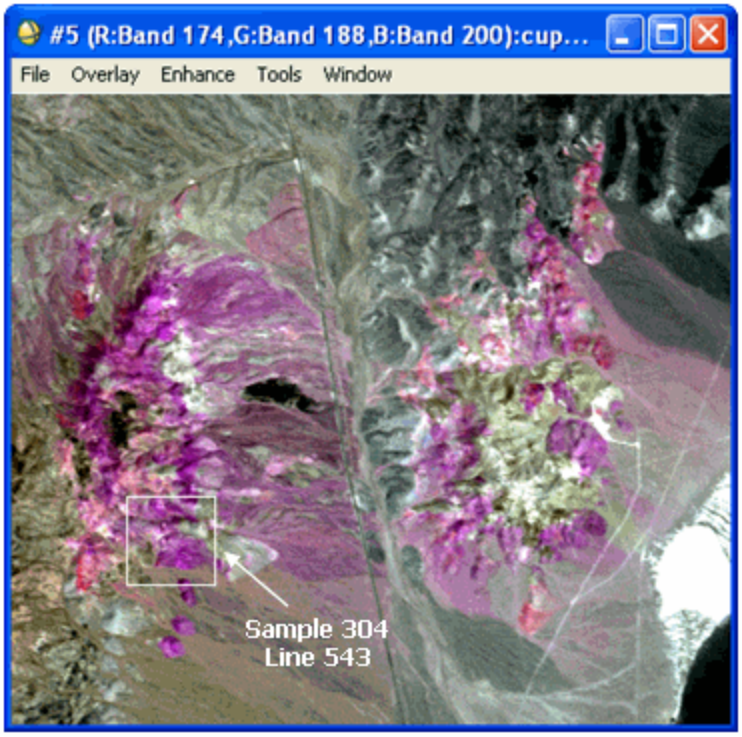
1. In the Available Bands List, click **Display #4** and select **New Display**.
2. In the Available Bands List, select **RGB Color**.
3. Scroll down the Available Bands List to the `cup95eff.int` image and choose Band 174 = **R**, Band 188 = **G**, and Band 200 = **B**, then click **Load RGB**.
4. Right click in the #5 Display group (the original image) and select **Pixel Locator**. The Pixel Locator dialog appears.
5. From the #5 Display group menu bar, select **Tools > Profiles > Z Profile (Spectrum)**. The Spectral Profile:`cup95eff.int` plot appears.
6. From the ENVI Classic main menu bar, select **Spectral > Spectral Libraries > Spectral Library Viewer**. The Spectral Library Input File dialog appears.
7. Select `jpl1.sli`, then click **OK**. The Spectral Library Viewer appears.

8. Click on **ALUNITE SO-4A**. The Spectral Library plot for Alunite appears.
9. Close the Spectral Library Viewer.
10. From the Spectral Library Plots menu bar, select **Edit > Plot Parameters**. The Plot Parameters dialog appears.
11. Change the **Plot Title** to **Alunite SO-4A** and the **Range** from **2.0** to **2.5**. Click **Apply**, then click **Cancel** to close the dialog.
12. Right-click in the #5 Display group and select **Link Displays**. The Link Displays dialog appears.
13. Link Display groups 2, 4, and 5 (the SAM classification image, the SID classification image, and the original image), then click **OK**.

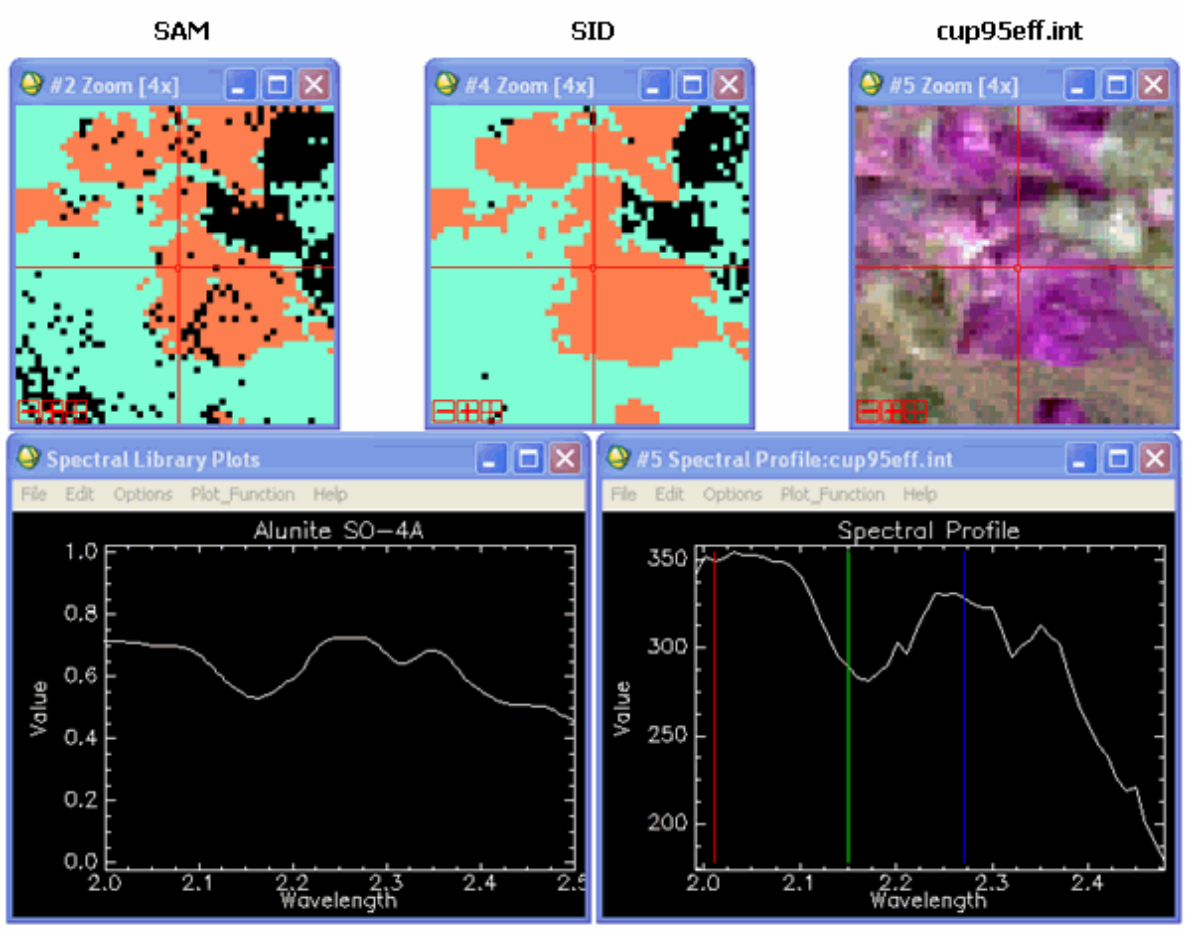
## Examining an Area Classified as Alunite

The first area you will examine is one that both SAM and SID classified as Alunite.

1. In the Pixel Locator, enter **304** for **Sample** and **543** for **Line**, then click **Apply**. The cursor moves to the specified area in Display groups 2, 4, and 5. When you compare the SAM and SID Display groups, you can see that both classified this pixel as Alunite because it appears as the coral color. In the original image, this pixel appears as purple.



2. Compare the Spectral Profile for this pixel to the known signature for Alunite SO-4A from the Spectral Library. The signatures are similar to each other, confirming that SAM and SID were correct in classifying this pixel as Alunite.

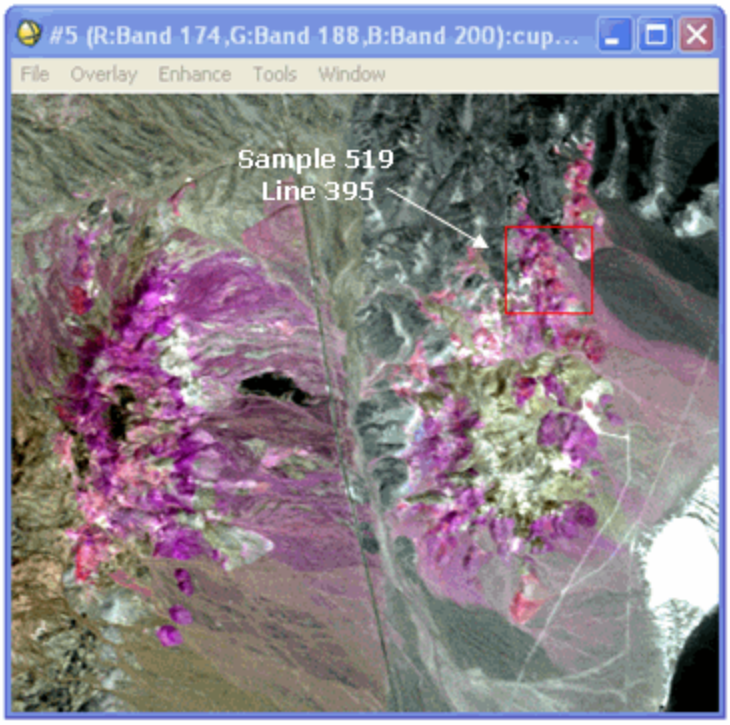



Known Alunite SO-4A signature and pixel (304, 543) spectral signature are similar

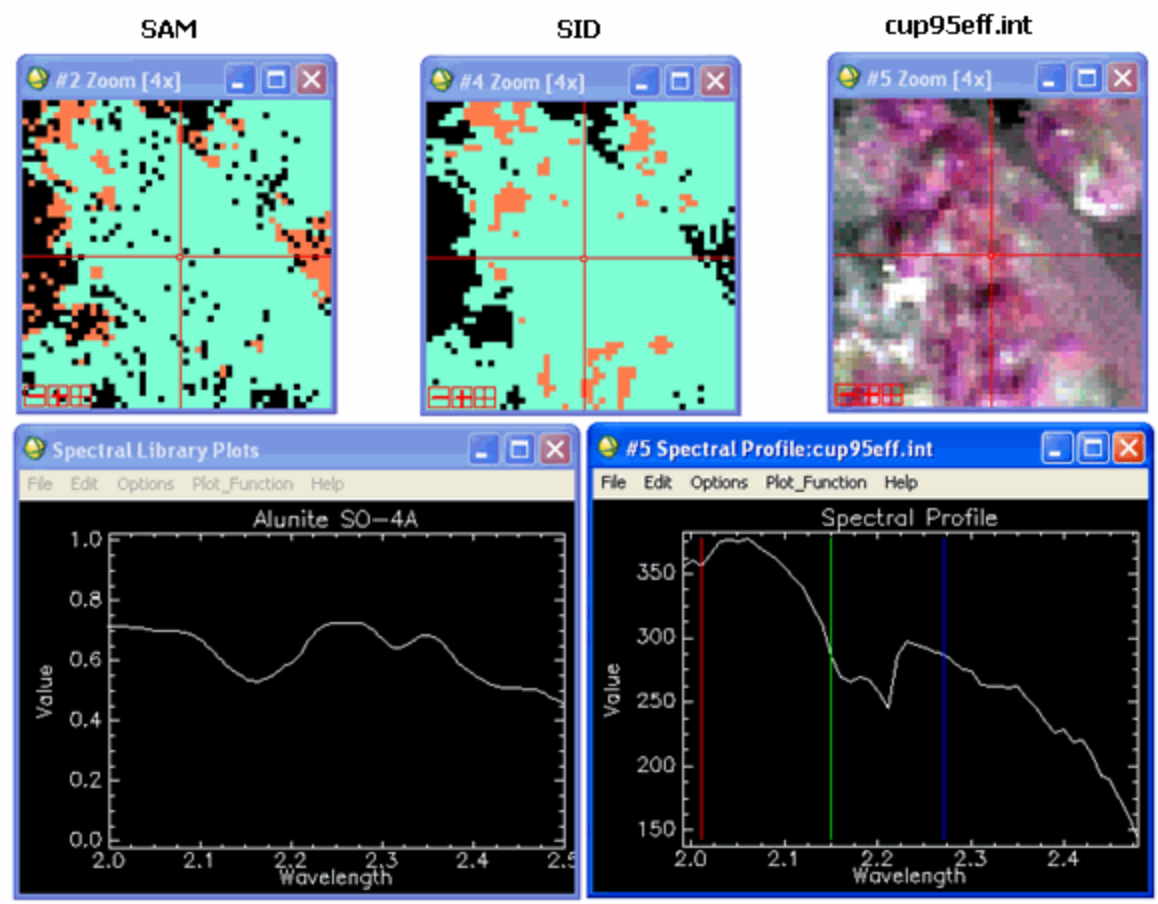
## Examining an Area not Classified as Alunite

The next area you will examine is one that neither SAM nor SID classified as Alunite.

1. In the Pixel Locator, enter **519** for **Sample** and **395** for **Line**, then click **Apply**. The cursor moves to the specified area in Display groups 2, 4, and 5. When you compare the SAM and SID Display groups, you can see that neither classified this pixel as Alunite. Instead, both methods classified this pixel as Kaolinite. In the original image, this pixel is not purple.




2. Compare the Spectral Profile for this pixel to the known signature for Alunite SO-4A from the Spectral Library. The signatures are not similar to each other, confirming that SAM and SID were correct in not classifying this pixel as Alunite. If you open a new Spectral Library plot containing Kaolinite, you will see that the Spectral Profile more closely resembles Kaolinite.

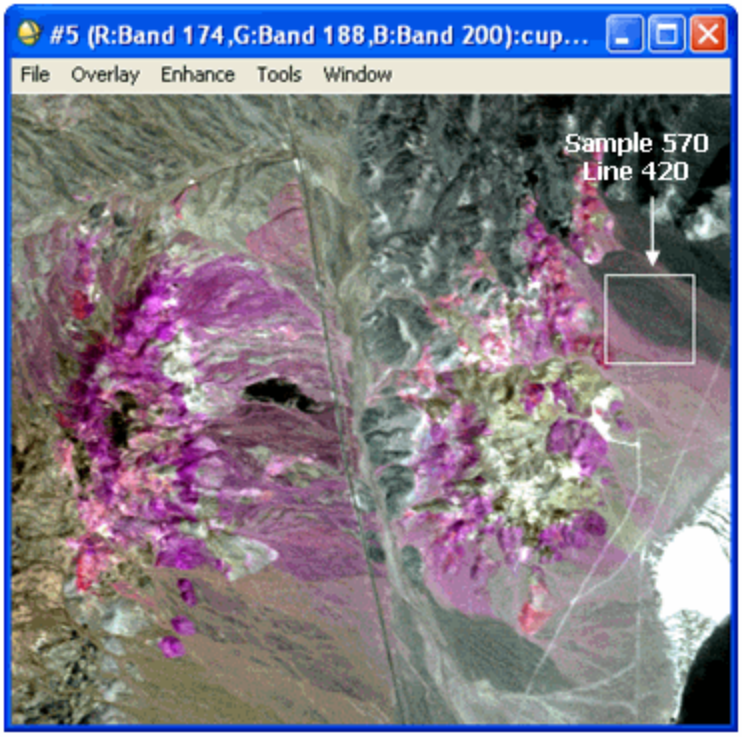



Known Alunite SO-4A signature and pixel (519, 395) spectral signature are not similar

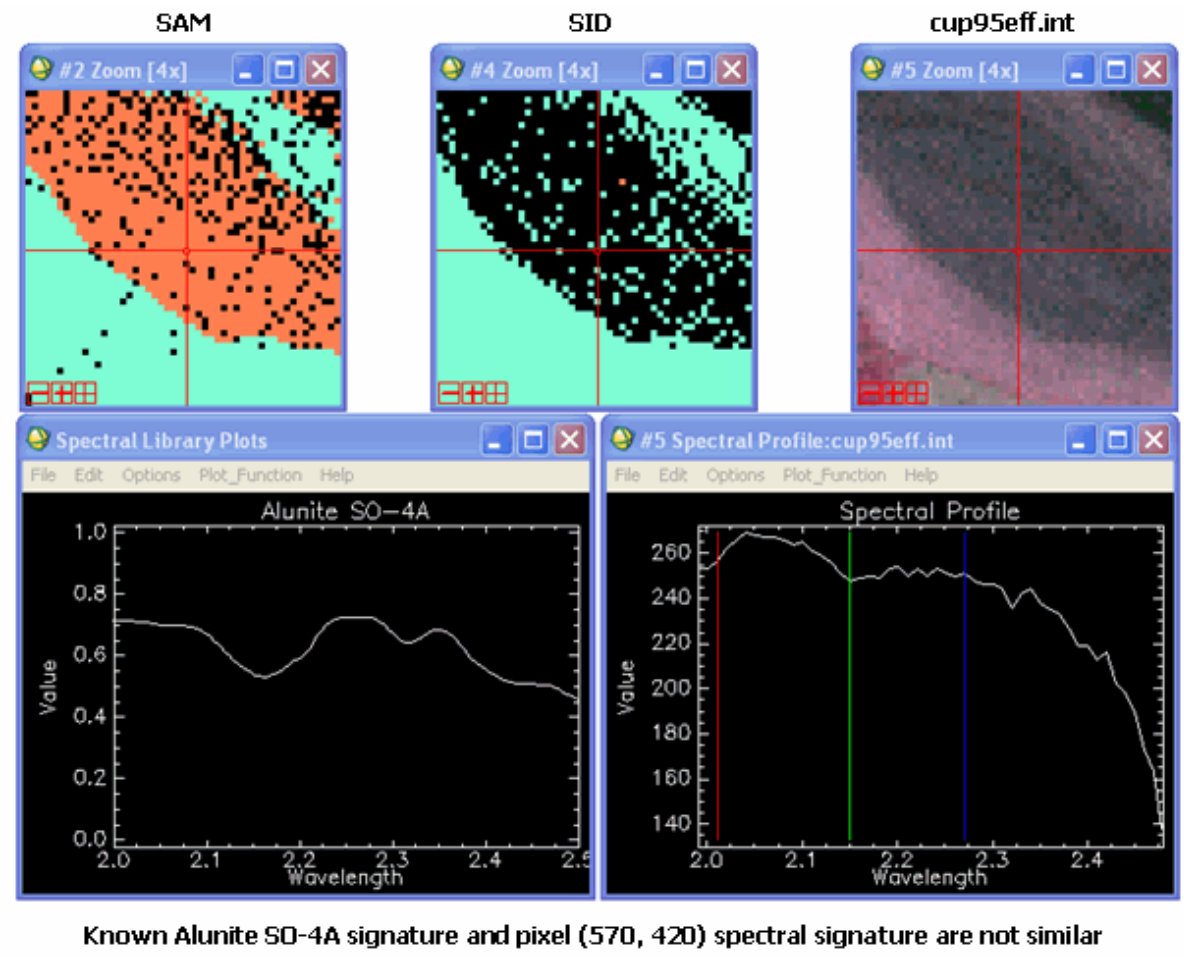
## Examining an Area Classified Differently by SAM and SID for Alunite

The last area you will examine is a large area in the upper right of the image that SAM classified as Alunite, but SID did not.

1. In the Pixel Locator, enter **570** for **Sample** and **420** for **Line**, then click **Apply**. The cursor moves to the specified area in Display groups 2, 4, and 5. When you compare the SAM and SID Display groups, you can see that SAM clearly classified this pixel as Alunite, but SID did not classify this pixel at all. In the original image, this pixel is not purple.




2. Compare the Spectral Profile for this pixel to the known signature for Alunite SO-4A from the Spectral Library. The signatures are not similar to each other. SAM classified this pixel as Alunite, but it is a false positive. SID was correct in leaving this pixel unclassified. It is neither Alunite nor Kaolinite.




**Known Alunite SO-4A signature and pixel (570, 420) spectral signature are not similar**

3. When you are finished examining results, you can quit your ENVI Classic session by selecting **File > Exit** from the ENVI Classic main menu bar.