

Lab 12 Change Detection and Radar Polarization

Utilizes Textbook's Remote Sensing Digital Database: Chapters 3 and 6 data.

The objectives of this lab are to learn three methods for documenting change on images over 16 days in central California and to evaluate the information provided by radar bands acquired with different polarizations.(see Chapter 9 Digital Image Processing for discussion). The change detection images and several files for the radar exercise are located in the **Lab_12_Data** folder. The tasks we will complete with this lab are done with tools in the **ENVI Toolbox**.

Three digital files are to be uploaded to the instructor and sixteen questions answered on the last pages of this handout.

Change Detection

We will analyze change at Mt. Diablo, California with Landsat images acquired before and after a fire. Much of the Mt Diablo exercise is courtesy of M.B. Quinn, Geography Dept., Diablo Valley College, Pleasant Hill, California.

NOTE: The two images used for change detection and band ratios need to have exactly the same number of rows and columns, and the same pixel size. When you cannot get the 2nd image to load in a change detection algorithm, check the Metadata and use the "Resize" tool to give the images the same dimension and same pixel size.

Change at Mt. Diablo, California: 7 September 2013 to 23 September 2013 (16 days)

Open ENVI

- 1) *Load* the two Landsat 8 TM subscenes into one View.

The datasets are in the **Lab_12_Data** folder.

mt_diablo_landsat8_7sep2013_30m_6band.tif

mt_diablo_landsat8_23sep2013_30m_6band.tif

Zoom to Full Extent

Change RGB Bands to reflected SWIR2 – NearIR – Green (Bands 6-4-2) as R-G-B so enhanced color images display

Contrast stretch with "Linear 2%" (SWIR2-NearIR-Green bands)

Perform Band Animation with the 6 bands on both Landsat images.

Load the DEM and hillshade DEM in the **Lab_12_Data** folder.

mt_diablo_30m_dem_

mt_diablo_30m_dem_shaded_

Drag the DEMs below the Landsat images in the Layer Manager.

The shaded DEM should be above the DEM.

Contrast stretch the DEM files with "Linear 1%"

Right-click the DEM > Change Color Table > Rainbow

Examine the hillshade and color-coded DEMs.

Select the hillshade DEM in the Layer Manager > “Transparency” slider >
 Fade the hillside DEM to 40%.

If needed, *drag* the 23 September image to the top of the Layer Manager.

Pan around the scene and *Zoom in* to the mountain. *Turn on and off* the 7 Sept and 23 Sept images so you see where features on the images are located on the color-coded hillshade DEM.

Question 1: A. What color is healthy vegetation in our enhanced color images (SWIR–Near IR–Green as R-G-B)?

B. September is a hot and dry month around Mt. Diablo, California, and typically follows many dry summer months. Based on our enhanced color images, what features around Mt. Diablo have the healthiest (most vigorous) vegetation?

C. What is the elevation at the top of Mt. Diablo? (DEM in meters)

Use the Data Manager to *load* a grayscale Band 4 (reflected near IR light) from the 7 September and 23 September Landsat data.

Zoom in to Mt. Diablo.

Contrast stretch both grayscale images “Linear 2%”. Press on the “Stretch on View Extent” icon (next to the contrast stretch drop-down menu) so only pixels within the View are used for the histogram and contrast stretch.

Question 2: A. Compare the 7 September band 4 to the 23 September band 4. Where geographically do you see the largest difference in brightness?

B. Based on what you see and can interpret, what event has the 23 September image captured on Mt. Diablo?

C. Based on the Landsat imagery, when did this event occur?

D. What Landsat spectral evidence do you have to support your interpretation about the event on Mt. Diablo between 7 and 23 September 2013?

2) In its simplest form, the difference between two images can be determined by subtracting one from the other: *Toolbox > Band Algebra > Band Math*

Enter the expression: “float (B1) – float (B2)” then “Add to List” > OK

The “float” within the expression allows negative (floating point) DN values in the output image.

Assign band 4 of the Sept 7 image as “B1”; *Assign* band 4 of the Sept 23 image as “B2”

Output filename: “lastname_bandmath”

Apply various (canned) contrast stretches. Apply the stretch that best identifies the difference between the two images.

Question 3: Explain how the band math subtraction of the 23 Sept image from the 7 Sept image results in the area of change having such a significant difference in brightness (DN value) compared to the surrounding area. (Hint: think what happened to the DN value of near IR pixels in the changed area compared to the DN value of near IR pixels in the surrounding area).

File > Chip View To > File > Format JPEG > “YourName_chg_bandmath”
Upload to the instructor.

3) Now let's try ENVI's change detection software:

Toolbox > Change Detection > Change Detection Difference Map

For the “Initial State” image, *select* band 4 of the September 7 scene, *> OK*

Select the September 23 scene (band 4) as the “Final State” image, *> OK*
Number of classes: 5

Select “Simple Difference” and “Standardize to Unit Variance”

Name the output file: “ Lastname_CDDM” (for Change Detection Difference Map)

The output image is a raster color slice showing various states of change relative to a mean DN value. The “plus” or “minus” indicate the positive or negative direction DN values have changed for each class. If your “LastName_CDDM” image was not automatically placed at the top of the Layer Manager by ENVI, select this file in the Data Manager and *> Load Data*.

ENVI's default (assigned) colors for classes are red (for positive values of change) and blue (for negative values of change). The user, however, can easily assign any color to each of the classes:

To change the color scheme:

Right-Click on the “Classes folder under the “lastname_CCDM” image *> Select*

“Edit Class Names and Colors” > the window pops-up
 > *Change Class Names and Class Colors* as you desire.

For this exercise, let's *change* the extreme change classes, 1 and 11.

Class 1: Change (+5) to Green

Class 11: Change (-5) to Yellow

Let's save as a jpg graphic.

File > Chip View To > File > Format JPEG > “YourName_color CCDM” > OK

Upload to the instructor.

3a) Individual or all of the classes can be exported to a more useful GIS polygon vector file (.shp format)

Toolbox > Classification > Post Classification > Classification to Vector

Select Input Band: the “Change Detection Difference Map” > OK

The “Raster to Vector Parameters” window pops-up

Select Classes to Vectorize > select “Change (-5)” this is Class 11

Accept defaults (Single Layer, output results to File)

Name the output file “Yourname_event_outline” in .evf format (ENVI vector format).

If the vector .evf file does not show up automatically in your Data Manager or Layer Manager, *File > Open > drive* to the folder where you saved your .evf file and *select “Yourname_event_outline.evf” (you must choose the file with .evf at the end) > Open*

Turn off all the files in your Layer Manager except the hillshade DEM. Your vector file looks excellent on the hillshade DEM!

Convert the .evf to .shp: *Toolbox > Vector > Classic EVF to Shapefile*

Name your shapefile “Yourname_CCDM_map_GIS.shp”

Recall that there will be at least three files associated with each ESRI shapefile (.shp, .shx, .dbf, & possibly a .prj file); so to not allow confusion in determining the difference between ENVI and ESRI files, provide a new, distinct name for the output shapefile(s).

Click-off all the layers in the Layer Manager. *Load* the shapefile into the View using the Data Manager (the shapefile may already be loaded in your view).

If the vector shapefile does not show up automatically in your Data Manager or Layer Manager, *File > Open > drive* to the folder where you saved your shapefile and select “Yourname_CCDDM_map_GIS.shp” (*you must choose the file with .shp at the end*) > *Open*

The shapefile map matches exactly the ENVI .evf map.

Zoom in to Mt. Diablo. Let’s send this vector map to the instructor.

File > Chip View To > File > Format JPEG > “YourName_CCDDM_shp” > OK

Upload to the instructor.

Close all files using the Data Manager.

NOTE: You can run a majority filter on the 11-class, event CCDDM classified raster image to reduce the number of small polygons. There are 733 polygons in this one shapefile!

In the GIS you can edit and eliminate small polygons – or all polygons outside of the main event feature – and create an excellent map with the feature of interest faded the hillshade DEM.

If you have access to a GIS, load the shapefile, Landsat images and DEM to evaluate. Look at the attribute table and note the area and perimeter calculations are provided for every polygon. So you can quickly provide area estimates to clean-up teams and environmentalists.

There is an ENVI tool named “Image Change Workflow”. This tool attempts to indicate “change” between two images by comparing differences using multiple bands rather than single bands (as were used in the examples we just completed). If you have time and want to try this alternative method of change detection, here’s the tool’s location.

ENVI Toolbox > Change Detection > Image Change Workflow

Close all files using the Data Manager. Start the radar exercise with a blank View.

Radar Polarization

We will analyze HH and HV polarized radar images from the Chapter 6 folder in the Digital Remote Sensing Database. We will also evaluate two ways to generate a third image from the HH and HV images so we can develop an informative color composite.

NOTE: Band ratios require the two grayscale images to have exactly the same dimension (rows and columns) and the same size pixels. If the 2nd image will not load in the band math tool or allow you to “Enter Pair” in the ENVI’s Band Ratio tool, you have to resize one of the images so that the rows and columns have identical dimensions.

Death Valley

We will process PALSAR-2 radar data of Death Valley, California and compare the radar to a Landsat 8 enhanced color image.

The textbook has PALSAR-2 characteristics in a Chapter 6 table along with a short description. See the textbook’s Figure 6-11 that shows a close-up of the PALSAR-2 HH and HV images in Death Valley.

1) *Start-up ENVI > Views > Two Vertical Views*

Drive to the “Plate 18_PALSAR-2_Sentinel-1_DV” folder and open the “PALSAR-2 L-band” subfolder.

The “...GeoTIFF” HH and HV bands are the original data and have their DNs in *unsigned integer* format. We’ll use these two images for band math.

The “...BW_Image_GIS” HH and HV bands were converted from the original number format to *8-bit (byte)* images that are easier to visualize in a GIS.

Highlight View #1 > File > Open

Select the unsigned integer HH GeoTIFF image:

“DeathValley_Palsar2_HH_2016_Resized_UTM12N_GeoTIFF” > Open

Highlight View #2 > File > Open

Select the unsigned integer HV GeoTIFF image:

: “DeathValley_Palsar2_HV_2016_clip_UTM12N_GeoTIFF” > Open

2) Link the Views and *Zoom in* and *pan* around Death Valley to compare the HH and HV imagery. Try different stretches. I found the obscure “Square Root” contrast stretch worked very well. See ENVI Help (definition below)

Square Root performs a square root gray scale transformation, then applies a linear stretch.

Question 5: Which polarized band carries more information to the untrained eye:
HH or HV?

3) We will use the band ratio to create a third grayscale radar image from the PALSAR-2 HH and HV images.

We will divide the DN of the pixels on the HH image by the DN of the pixels on the HV image to generate a ratio grayscale image. The “Committee on Earth Observation Satellites” (CEOS) notes that the HH/HV backscatter ratio is commonly used with PALSAR (L-band) data and displayed in the blue channel as it results in a color composite image in which vegetated areas appear green.

We can use either band math or the “Band Ratios” tool.

With band math the formula becomes:

$\text{float (b1) / float (b2)}$

ENVI Toolbox > Band Algebra > Band Math

In the “Band Math” window:

Enter the expression above > Add to List, and then > OK

click on the HH image for B1 and the HV image for B2 > OK

Name the output: “DeathValley_HH_HV_Ratio _radar”

The ratio image will appear in one of the two vertical views.

Let’s create a 4-View display. *Views > 2 x 2 Views > OK*

Highlight the empty View #3

Drag the “DeathValley_HH_HV_Ratio _radar” to View #3

(*remove* from View 1 or 2)

or load the ratio image into View #3 from the Data Manager.

Views > Link Views > Link All > OK *Zoom to Full Extent*

Zoom in and *pan* around to compare the 3 grayscale images:

HH, HV, and HH/HV

Question 5: Describe the ratio (HH/HV) image in 10 words or less.

Now we want to stack these HH, HV and ratio images into a 3-band color image.

Highlight the empty View #4

ENVI Toolbox > Raster Management > Layer Stacking

Import the 3 files by selecting all 3 files > OK

Reorder if necessary:

The stack should be from top to bottom: HH, HV, HH/HV Ratio.

(or HH – HV – HH/HV Ratio Image as R – G – B (1-2-3))

Accept the defaults.... > Output Filename:
 "DeathValley_HH_HV_ratio_radar" > OK

Load the HH-HV-ratio color composite into View #4

Views > Link Views > Link All > OK

Try different stretches on the HH-HV-ratio color composite.

4) You should have

HH in View 1,

HV in View 2,

HH / HV ratio grayscale in View 3, and

HH-HV-band ratio color composite in View 4

Views > Link Views > Link All > OK

Question 6: Do you think the color composite (View 4) tells you more information about Death Valley compared with the grayscale HH and HV? YES NO

5) *Right-click* on View #1 (HH Band) in the Layer Manager and > *Remove View*

Right-click on View #2 (HV Band) in the Layer Manager and > *Remove View*

In the View with the HH/HV ratio, load the **Landsat** color image.

Highlight this View *File > Open*

Drive to the

"Plate 18_PALSAR-2_Sentinel-1_DV \ Landsat8" subfolder
 and *select*

"DeathValley Landsat8_P40R35_22Feb2017_752 Enh-Color_30m_Image_GIS"

> *Open*

Zoom to Full Extent The Vertical two Views should be linked.

Zoom-in and *pan* around to compare the enhanced Landsat that is generated from reflected SWIR2, Near IR, and blue light with the radar color composite that is generated from reflected radar energy.

Question 7: A. On the radar images there are dark features along the bottom of the valley. What does the dark tone indicate about the roughness of the surface?

B. On the HH-HV-Ratio color radar image of the valley bottom (ignore the mountains on the left and right) there are bright landforms with colors that grade from yellow to light purple to darker purple. What does gradation in brightness indicate what about the surface roughness of those landforms?

Close all files with the Data Manager. You should have two Views - *Select View #1*

Trinity River, Texas

We will close the lab with HH and HV polarized radar data collected by the European Space Agency's excellent Sentinel-1 satellite. The textbook lists characteristics of the Sentinel-1 system in a Chapter 6 table. Plate 51 (Chapter 15) in the textbook shows an interferogram generated from Sentinel-1 system that measured ground deformation caused by the 2014 Napa Valley, California earthquake.

1) *Start-up ENVI > Views > Two Vertical Views Highlight View #1.*

File > Open Drive to the Remote Sensing Digital Database \ Ch_6_Radar_Images" folder.

Open the "ESA_Sentinel-1_hh-hv-ratio" subfolder and

Select the "Galveston_2017Apr14_Sentinel-1_hh-hv-ratio_GIS" image > Open
The radar image should load into View #1.

Highlight View #2.

Return to the "ESA_Sentinel-1_hh-hv-ratio" folder

Select the "Landsat_OLI_432_6Apr2017_clip_GIS" image > Open
The Landsat image should load into View #2.

Views > Link Views > Link All > OK

Zoom to Full Extent

You can see the overlap area of the radar and Landsat is mostly East of the Trinity River and Houston.

2) Both images were acquired within 8 days in 2017 (!) We can have some confidence that features of interest on the radar and Landsat did not markedly change over the 8-day period. We will examine the advantages of using radar in urban and coastal areas.

Zoom-in and pan around The Sentinel-1 image is not georeferenced very well, so offsets will be noticed by you as you zoom-in and pan around.

3) *File > Open Highlight View #1 with the Sentinel-1 radar color image.*

Drive to the **Lab_12_Data** folder and *select* the Shapefile and ENVI ".anz"

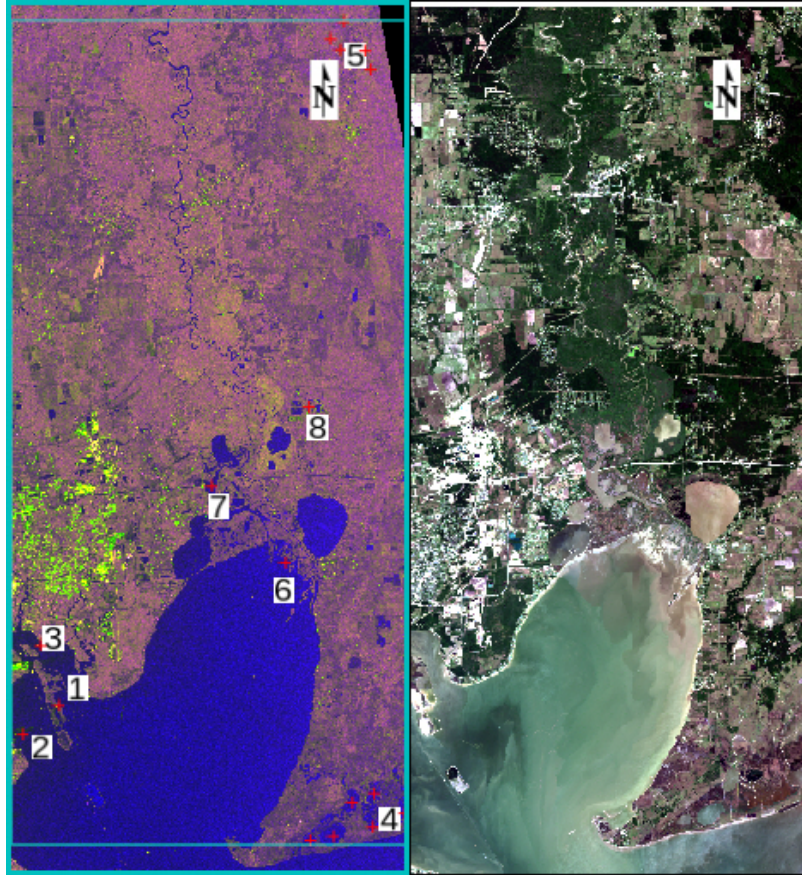
(8 sites are located with points and labels in the Shapefile and the .anz file).

select "Sentinel-1_Radar_Sites.shp" > Open

(There are at least 6 other files associated with this GIS shapefile).

Also *select "Sentinel-1 Sites for Eval.anz" > Open*

The shapefile is a point vector file with attributes. The ENVI .anz file is just an annotation file that posts Site numbers 1 – 8 in the View. They should be posted on the Sentinel-1 radar image in View 1 as shown below.



The shapefile's attribute table is also available as an Excel spreadsheet "Shapefile Coordinates Eval Sites.xls" in the **Lab_12_Data** folder.

The Shapefile's Attribute Table is shown below. You can copy & paste the Lat/Long numbers in each row into ENVI's Go To drop-down window as "29.641, -95.936" and ENVI will place the crosshairs at that location.

The Shapefile's Attribute Table from the Excel Spreadsheet.

Site	Name	Lat	Long	Y	X
1	Mouth of river	29.641	-94.936	3280587.0	312598.7
2	bright dots on radar	29.690	-94.956	3286019.9	310785.3
3	submerged pattern on radar?	29.618	-94.974	3278049.1	308854.1
4	ponded water	29.562	-94.625	3271356.9	342531.7
4	ponded water	29.569	-94.603	3272150.7	344754.2
4	ponded water	29.566	-94.556	3271674.4	349278.6
4	ponded water	29.553	-94.570	3270325.1	347849.9
4	ponded water	29.531	-94.670	3267996.7	338166.1
4	ponded water	29.598	-94.552	3275193.4	349675.5
4	ponded water	29.542	-94.604	3269108.0	344595.5
4	ponded water	29.535	-94.645	3268340.7	340573.8
5	Ag Fields	30.185	-94.649	3340383.0	341270.7
5	Ag Fields	30.176	-94.638	3339414.4	342284.4
5	Ag Fields	30.175	-94.612	3339279.2	344796.0
5	Ag Fields	30.160	-94.606	3337578.5	345359.2
5	Ag Fields	30.198	-94.634	3341903.5	342667.3
6	Tide	29.758	-94.696	3293135.1	335999.7
7	Interstate 10 Bridge pilings?	29.820	-94.774	3300160.4	328553.2
8	industrial site	29.885	-94.671	3307191.2	338601.4
				WGS-84	UTM 15N

NOTE: ENVI apparently cannot display attributes as labels (such as the Site number) in the ENVI View. And I cannot make the “Cursor Value” Tool reveal any attributes from a shapefile vector point displayed in the ENVI View. Let me know if I’m wrong. All the shapefiles have to go to a GIS to be useful and to be able to be queried?

If the vector files don’t work for you, just *copy* Lat, Long coordinates (separated by a comma) from the table above, *zoom-in* to the crosshair, and answer the questions below concerning Sites 1 to 8.

4) Let’s analyze what new information is available in the Sentinel-1 radar image.

Zoom-in to **Site 1** at the mouth of the Trinity River and Galveston Bay. If the large ENVI annotation numbers block your view, just *unclick* the .anz file in the Layer Manager.

You can increase the size of the shapefile’s points “+” by *right-click* on the shapefile in the Layer Manager > *Properties* > *Point Size* > *increase* the size from default “8” to “12” or “16” or more – and you can change the color of the “+” > *Apply* > *OK*

Answer the following questions concerning Sites 1 to 8.

Question 8: Site 1. What different type of information is provided by the radar image versus the Landsat natural color image for the nearshore feature with many large polygonal structures?

Question 9: Site 2: Do you see the green pattern to the northwest of “2” on the Landsat? What could cause this feature – what could it be?

Question 10: Site 3: These bright dots in a line on the radar are not seen on the Landsat. What is a “corner reflector” in the science of radar?

Question 11: Site 4: A. Why is radar more reliable for visually detecting ponded water compared to Landsat that captures reflected visible light?

B. What are you seeing on the surfaces of the ponds in the Landsat image?

Question 12: Site 5: A. Why are there shadows on the west side and illuminated edges on the east side of the agricultural fields with the “red +” ?

B. Are the fields higher or lower than the surrounding land cover?

Question 13: Site 6: Which image shows the tide is out (low tide): radar or Landsat?

Question 14: Site 7: This is the east-west Interstate 10. What do you think the bright dots are on the radar image?

Question 15: Site 8: Compare the radar and Landsat images of the industrial ponds and surrounding area.

A. Purple-violet on the radar image indicates what type of land cover?

B. Green – yellow green on the radar image indicates what type of land cover?

C. Why are many north-south roads clearly visible on the radar and east-west roads are more difficult to see?

This exercise hopefully shows that polarized radar imager can provide unique information in wetlands, coastal, industrial, and agricultural landscapes. There are radar systems that collect 4 polarizations and multiple wavelengths – these extract more information about the Earth’s surface features. The Sentinel-1 satellite radar imagery is available for download at no cost from ESA.

Lab 12 Change Detection and Radar Polarization Name:

Upload the following files to the instructor:

(2) "Your Name_chg_bandmath" jpg

(3) "YourName_colorCCDM" jpg

(3a) "YourName_CCDM_shp" jpg

Question 1: A. What color is healthy vegetation in our enhanced color images (SWIR–Near IR–Green as R-G-B)?

B. September is a hot and dry month around Mt. Diablo, California, and typically follows many dry summer months. Based on our enhanced color images, what features around Mt. Diablo have the healthiest (most vigorous) vegetation?

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