Synthetic Aperture Radar

Land Applications

III B

Model answers to the Bilko exercise

prepared by

Introduction

This SAR Land Applications Tutorial has three main components:

I. Background and theory - an overview of the principles behind SAR remote sensing, data processing techniques, examples of land applications, and current and future sources of SAR data. This includes questions to test student understanding of the material.

II. This Bilko Exercise - providing hands-on experience in the processing and interpretation of alternating polarisation (AP) data from Enivsat-ASAR.

III. Answers

This section (III B) provides model answers to go with the activities and questions in the Bilko exercise. Answers to the theory questions can be found in section III A, which is available as a separate document.

The answers and screenshots section provided here complement section II of the tutorial, allowing users to check their own understanding as they work through the practical exercises.

These model answers are not just intended as a short check on whether an answer is correct or not, they also aim to identify relevant background information and explain the reasoning and practical steps used in order to arrive at the solution.

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Bilko Exercise - Answers to Question 1

a) The start and stop times are found in the Metadata, in the Main Product Header (MPH)

SENSING_START = 18-DEC-2003 01:43:30.400929

SENSING_STOP = 18-DEC-2003 01:43:47.296527

b) The orbit number is given in the MPH section of the Metadata.

REL_ORBIT = 332 ABS_ORBIT = 9404

The SPH tells you that this image was obtained on a descending pass.

c) The pixel spacing is given in the special product header (SPH):

RANGE_SPACING = 7.80397463 AZIMUTH_SPACING = 3.21221614

The figure in Slide 9 of the Theory Section explains range and azimuth: Range (across track) spacing corresponds to distance between columns (pixel size in the X-dimension). Azimuth (along track) spacing corresponds to distance between lines (pixel size in the Y-dimension.

d) There are two measurement data sets (MDS) i.e. 2 bands. The SPH explains what these are:

MDS1_TX_RX_POLAR = H/V and MDS2_TX_RX_POLAR = H/H

In both cases the transmitted signal (TX) was horizontally polarised. MDS1 is the record of the vertical polarisation component (V) of the return signal (RX), and MDS2 is the record of the horizontal polarisation component (H) of the return signal

Bilko Exercise - Answers to Question 2

a) Section 1.6 Data Statistics tells you that SLC (Single Look Complex) data consists of a real and imaginary part, also known as in-phase and quadrature channels.

b) Right-clicking on the images and selecting Open Properties from the menu tells you that image i (in-phase) contains the real part and image q (quadrature) contains the imaginary part of the data.

c) The explanation of SLC, Amplitude and Intensity (Section 1.6 SAR Data Statistics) shows you how Amplitude (A) is related to i and q. As Power (or Intensity) is equal to Amplitude squared, the Power, P, may be caculated from I and q as follows:

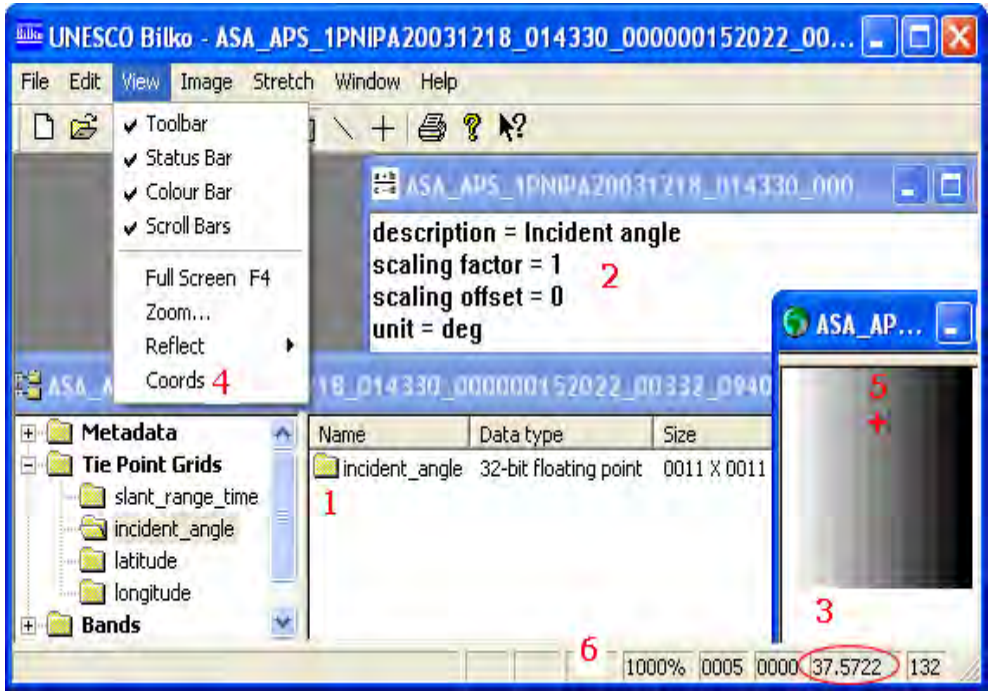
$$P = A^2 = i^2 + q^2$$

Bilko Exercise - Answers to Question 3

a) The following information is required in order to calculate the number of looks:

Pixel spacing in azimuth (from Metadata, SPH):	3.21m
Pixel spacing in range (from Metadata, SPH):	7.80m
Look angle (from Tie Point Grids):	37.57 degrees

The Look Angle can be found by opening the 11x11 data-set incident_angle (see figure below).



1. Select the incident_angle folder.
2. Open the folder properties by right-clicking on its icon in the right frame.
3. Open incident_angle by double clicking on its icon in the right frame. Right-click on the image. Select Zoom, and set the Zoom to 1000%.
4. Open the View menu, and change the coordinates used from lon/lat to x/y by clicking on Coords in the drop-down.
5. Place the cursor in the middle column.
6. Read the central look angle from the Bilko status bar.

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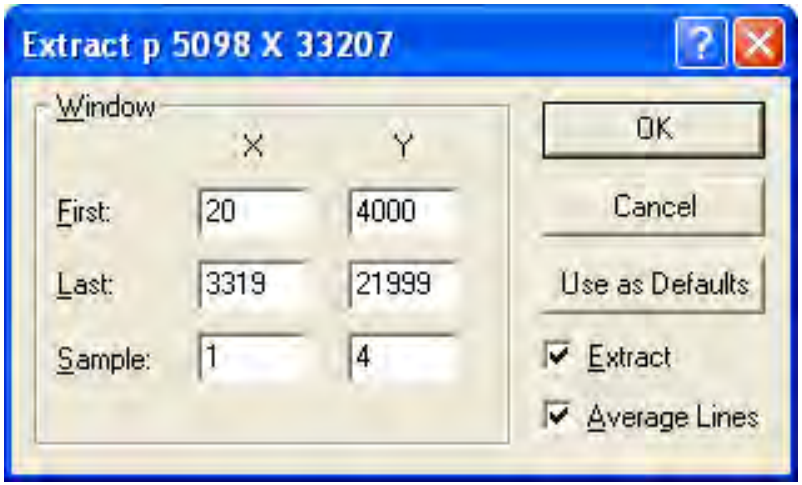
Bilko Exercise - Answers to Question 3 (cont.)

b) The ground resolution in range can be calculated from the pixel spacing in slant range.

Ground resolution = pixel spacing / sin (look-angle) = 7.80 / sin (37.57deg) = 12.80 m

c) The equivalent pixel spacing in azimuth is 3.21m x 4 = 12.84 m

d) To open the area of interest while converting to an appropriate ground resolution the Extract box should be set as shown in the figure below:



Bilko Exercise - Answers to Question 4

a) The three GCPs given in the table show the following features:

[2566,643] Bridge across the river

[2493,914] End point of land where a smaller river flows into a larger river

[1540,695] Highly reflective man-made structure, possibly a building

b) The appriximate position of the three GCPs, and the difference between the images calculated from these positions are given in the table below.

Image:	20031113		20031218		20040122		Adjustment		Adjustment	
Pixel Coordinates	x11	y11	x12	y12	x01	y01	x11-x12	y11-y12	x01-x12	y01-y12
Bridge	2563	852	2566	642	2553	768	-3	210	-13	126
Confluence	2490	1126	2492	914	2476	1040	-2	212	-16	126
Building?	1537	906	1541	695	1526	822	-4	211	-15	127

Note that it is often difficult to establish the exact pixel position of even a clearly defined feature such as a bridge or a building. The coordinates you noted down may well vary from the ones given below by a pixel or two. For this reason it may be worth selecting a number of ground control points and use these to give some idea of the accuracy of the co-registration.

c) December: First column and row, [x,y] = [20,4000]; last column and row [3319,21999].

November: First: X=20-3=17, Y=4000+211*4=4844 (where 4 is the number of looks).

Last: X=3319-3=3316, Y=21999+211*4=22843

January: First: X=20-15=5, Y=4000+126*4=4504

Last: X=3319-15=3304, Y=21999+126*4=22503

Bilko Exercise - Answers to Question 5

a) Assuming that the position error in matching GCPs between images is random, the 95% confidence limit is +/- 2 standard deviations from the mean position. This corresponds to just over 2 pixels (see table).

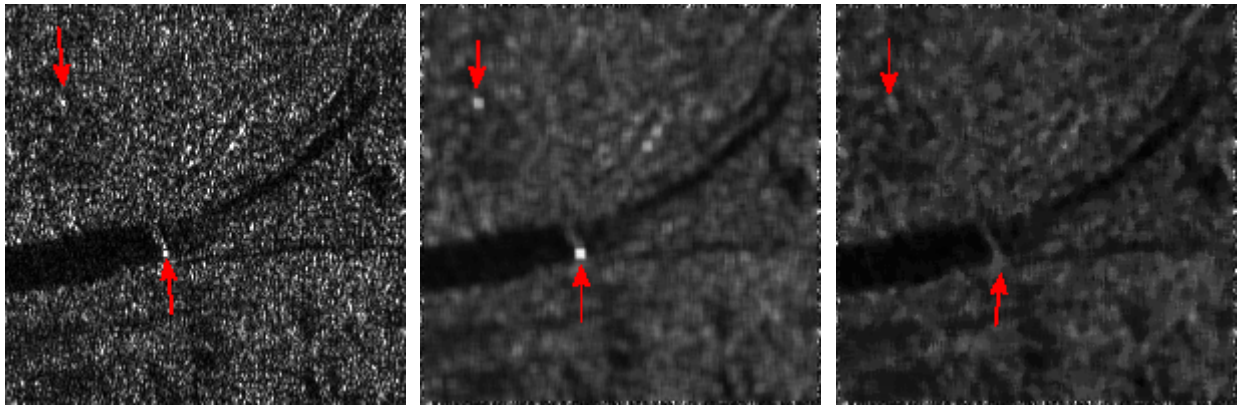
Pixel Coordinates	x11-x12	y11-y12	x01-x12	y01-y12
Mean difference	-3.4	210.9	-14.0	126.3
Standard deviation (s)	1.1	1.1	1.2	1.2
95% limit	2	2	2	2

Note that the co-registration you have carried out here does not take account of the slight changes in pixel size that are a result of changes in viewing angle across track. This difference is included in the error given by the 95% confidence limit above. More specialist software often include automated co-registration routines that use orbital considerations to calculate the adjustments required. Such routines are described in the Theory part of the tutoria, section 2.1.3 Co-registration.

b) The effect of poor co-registration could potentially give rise to large error in the calculated ratios along boundaries between areas of different land use. This effect would be particularly markded if the change in radar backscatter across boundaries are large.

c) Differences in look-angles means that the distance on the ground covered by one pixel in a slant range image changes in range (across track). The difference it look angle to a point on the ground in overlapping images from different parts of the orbital cycle may be quite large, and coregistration of such images therefore requires the differences in look-angle and pixel size to be accounted for in the co-registraton.

Bilko Exercise - Answers to Question 6



Original image (left), mean filtered image (middle) and median filtered image (right). Not the differences in how point features lines and edges are affected by the filters.

a) In the mean filtered image the salt-and-pepper apppearance of the original is changed to larger areas of grey. Speckle is reduced at the cost of blurring the boundary between features. Hence the outline of the river is less sharp, and some bright point features (red arrows) are enlarged. This is due to the averaging performed by the mean filter, which means that a single very bright pixel will affect every 5x5 square in which it is included.

b) The median filter also reduces speckle, but does not blur the outline of the larger river or the bridge across it. However, some bright point features are lost. The median filter removes very low and very high data values, replacing these with the median value of the 25 pixels in the window. This makes it better at retaining the boundary between areas with different signal return, but means that very bright or dark point features are lost. (cont.)

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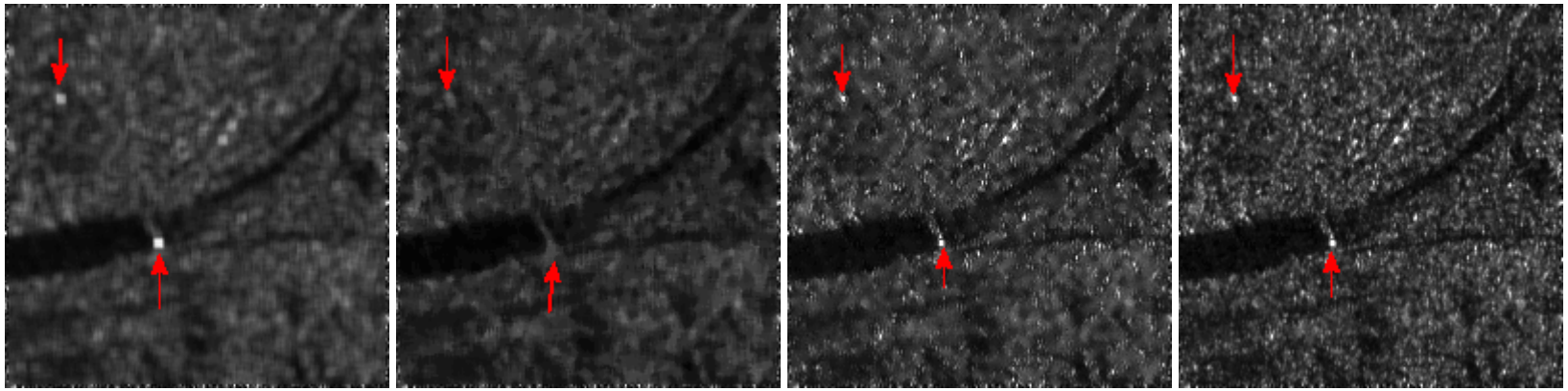
Bilko Exercise - Answers to Question 6 (cont.)



From left to right, mean, median, Lee and Frost filters. Look for their ability to reduce speckle, while retaining line and point features, and edges between larger areas of different brightness.

c) The Lee filter retains boundaries, point and line features better than the mean and median filters, but some very bright speckle pixels are retained. The high covariance in the filter window around such pixels means a greater proportion of the original value is included in the output. The extent to which this is done depends on the specified number of looks, as the covariance is expected to be lower in multi-looked data. Reducing the specified number of looks will remove more of these bright pixels, but some finer point and line features may also be lost.

d) The Frost filter retains point features, lines and boundaries more clearly than mean and median, and is less prone to retaining the speckle of very bright pixels.

e) Based on this exercise the Frost filter would seem the best choice.

Bilko Exercise - Answers to Question 7

a) The November image is mapped to red, the December image to green and the January image to blue.

b) Areas that are significantly brighter in the November image than in the December and January images appear red, as the brightness in the red channel (November) is much greater than in the blue and green channels (December January). Areas with little change from one month to the next will appear grey.

The second rice-crop season in the Philippines is in the period December-April (see Exercise overview), so it is likely that the change in SAR reflectivity after November to December is due to the emergence of rice plants, which have a lower reflectivity than the bare soil. The colour is thus an indicator of agricultural land.

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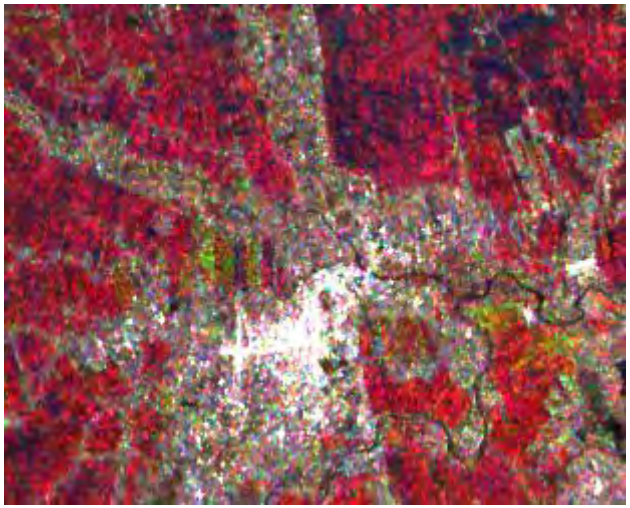
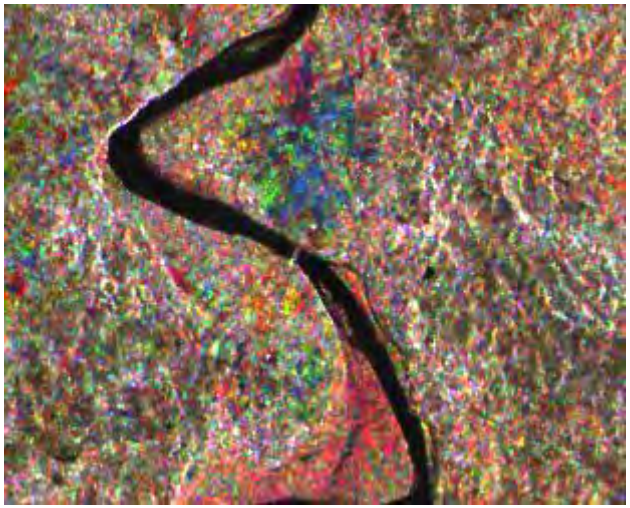
Bilko Exercise - Answers to Question 7 (cont.)

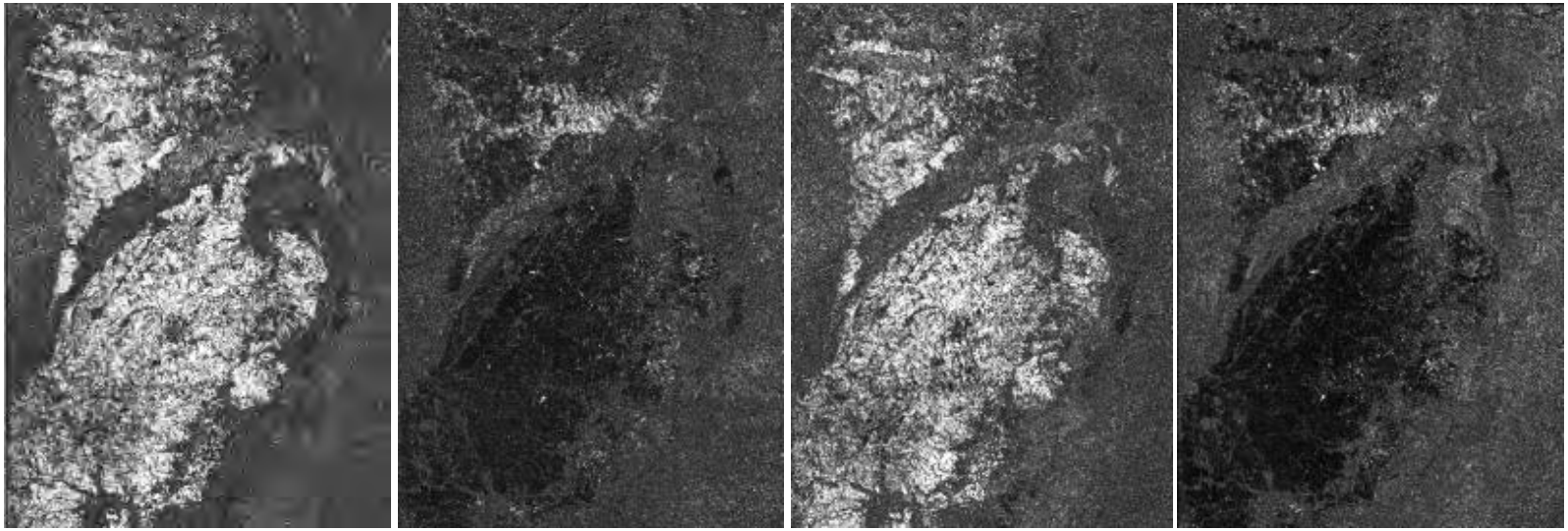




c) City streets or buildings are lined up to create a double bounce reflect the signal directly back towards the radar and appear white (section 1.4.3). Built up areas where no double bounce occurs are slightly darker, like very rough surfaces. The white and grey areas are urban areas, and changes in vegetation are therefore small.

d) Flat surfaces such as smooth bodies of water (the river) scatter the radar signal away from the sensor, so they appear dark. The river is uniformly dark gray/black, so it's properties do not vary much from one month to the next – it is a permanent body of water. In contrast the bridge and land are brighter – i.e. the surface is rougher. In this part of the river valley the overall colour is not far from grey, indicating that there are no dramatic changes in scattering properties from one month to the next. One exception is a blue area to the east of the river meander; the colour of this shows that scattering by this area increased after November.

Bilko Exercise - Answers to Question 8



From left to right, HV polarisation, Nov/Dec and Dec/Jan; followed by HH polarisation Nov/Dec and Dec/Jan, all displayed with a linear stretch from 0-5. Note how the areas that are bright in the Nov/Dec ratio images are generally dark in the Dec/Jan images.

The 4 ratio images show the radar backscatter signal changes from month to month for cross-polarisation (HV) and co-polarisation (HH) data. In the bright areas there is a marked drop in the in signal return from one month to the next; most marked for November to December. In the dark areas there is an increase in signal return with time; this occurs mostly from December to January. The mid grey areas are regions where there is no marked change from month to month.

Bilko Exercise - Answers to Question 9

a) The filter window is centred on the pixel that will receive the output of the filter. For a 7x7 filter window (see figure on the left) the three edge rows and columns will therefore be surrounded by filter windows that are partly outside the image area. These pixels will not be filtered and are thus best removed from the image before further processing. For a 15 x 15 filter window 7 rows and columns on the edge of the image would have to be removed.

b) As explained in the Bilko help file on Principal Component Analysis the Covariance Matrix is usually used for analysis of multi-channel image data. For temporal analysis – studies of how an area changes over time – the Correlation Matrix is generally used.

Bilko Exercise - Answers to Question 10

a) The PCA generates two tables. The first shows the correlation matrix, which gives the correlation between pairs of ratio-images (below left). The second shows the PCloading – i.e. the correlation between the principal components and the original ratio images (below right).

Table1

Correlation	ratio_dec_jan_hh	ratio_dec_jan_hv	ratio_nov_dec_hh	ratio_nov_dec_hv
ratio_dec_jan_hh .	1.0000	0.5300	-0.4031	-0.3369
ratio_dec_jan_hv .	0.5300	1.0000	-0.2767	-0.3996
ratio_nov_dec_hh	-0.4031	-0.2767	1.0000	0.6266
ratio_nov_dec_hv	-0.3369	-0.3996	0.6266	1.0000

Table2

PCA	pc1	pc2	pc3	pc4
ratio_dec_jan_hh ...	0.7432	0.4367	0.4659	0.1996
ratio_dec_jan_hv ...	0.7170	0.5246	-0.4060	-0.2142
ratio_nov_dec_hh...	-0.7715	0.4844	-0.2340	0.3397
ratio_nov_dec_hv...	-0.7918	0.4130	0.2977	-0.3375

b) Right: Contribution to the variance from each of the 4 PCs, calculated as the sum of squares of each PC loading divided by 4. This shows that the first 3 PCs are responsible for over 92% of the variability.

	PC 1	PC 2	PC 3	PC 4
ratio_dec_jan_hh.dat	0.7432	0.4367	0.4659	0.1996
ratio_dec_jan_hv.dat	0.717	0.5246	-0.406	-0.2142
ratio_nov_dec_hh.dat	-0.7715	0.4844	-0.234	0.3397
ratio_nov_dec_hv.dat	-0.7918	0.413	0.2977	-0.3375
% contribution to variance	57.21%	21.78%	13.13%	7.88%
Cumulative contribution	57.21%	78.99%	92.12%	100.00%

c) PCs 1 and 2 show clear patterns of variability similar to those seen in the ratio images. In contrast PC 3 shows only a faint indication of this pattern, on a general back-ground of high-frequency variation. This 'salt and pepper' pattern, which is typical of speckle becomes more prominent if the Redisplay stretch for this PC is changed to Autolinear. This indicates that much of the variability iis due to insufficient removal of speckle during filtering.

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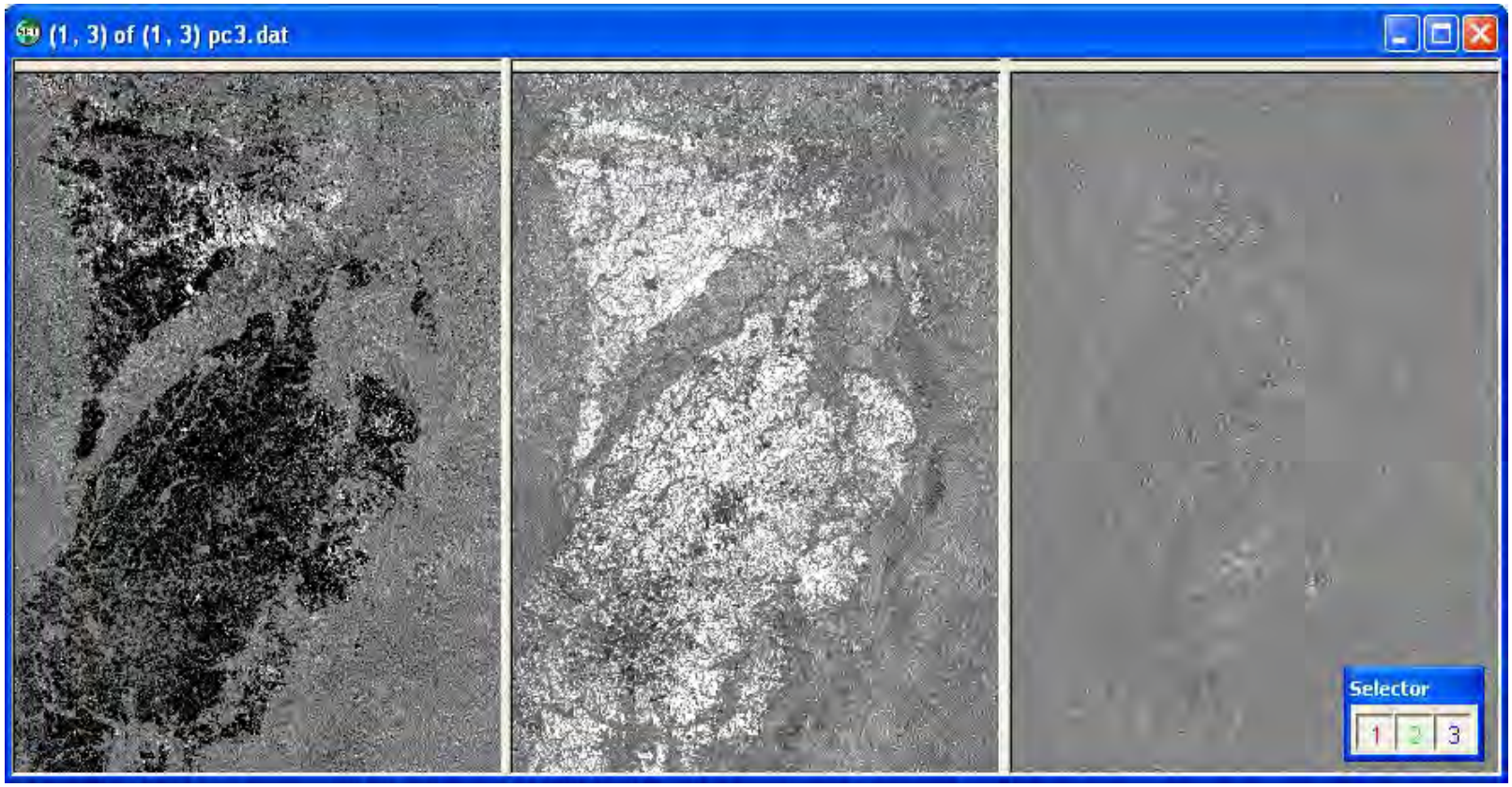
Bilko Exercise - Answers to Question 10 (cont.)



Bilko set of the first three PCs, from left to right, 1,2 and 3. While 1 and 2 show clear patterns of change, these are much fainter in PC 3, which also seems more noisy.

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Bilko Exercise - Answers to Question 10 (cont.)

d) The colour composite of the first three PCs show three clear categories of land shown in colours of green, yellow and grey, and indications of a third category, purple. The grey areas have values near 0 in all the PCs and represent land with minimal change in scattering over time - i.e. land without emerging or growing crops. Green and yellow are areas with a marked change – i.e. fields with emerging crops. Green areas have high values along PC2 but not along PC1, while yellow has high values along both 1 and 2. Purple areas have high values along PCs 1 and 3.

e) The green areas are broadly those shown in the rice map of section 3.9 to have crops emerging in the period 18/12-22/1. The pale yellow areas are broadly those marked as emerging in late January in this map.

f) Unlike the composite based on the hv images, this one is based on analysis of the ratio images, where all areas that do not change have a ratio of roughly 1 regardless of their brightness in the original images.