**Research Article**

# An Open Source Free Downloadable GUI Based Image Processing Software for Performing Various Mathematical and Statistical Operations on Remote Sensing Images

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**Abstract** Effective interpretation of remote sensing images acquired by space borne and air borne sensors requires various mathematical and statistical operations to be applied to them. Importance of use of various mathematical and statistical operations on Remote Sensing Images enhances manifold if the research/project work requires analysis of large number of these images. A large number of commercial image processing software are available in the market to support the requirement of implementation of various Mathematical and Statistical operations on remote sensing images. However, the cost of commercial software is very high; therefore, they are not affordable by schools and few institutes where sufficient funding is not available. Looking at the requirement of a freely available image processing software to perform various mathematical and statistical operations on large number of remote sensing images or a multi-band image, a GUI based image processing software has been developed to help those who want to work and explore remote sensing data but doesn't have sufficient funds to purchase costly software. Based upon the objective of the software, the name of the software has been decided as MASC (Mathematical and Statistical Calculator). This paper is about 'MASC' GUI which performs operations similar to 'mathematical and statistical operations on various bands' tool of some of the commercially available software. 'MASC' software is very useful in image enhancement and interpretation. The aim of this paper is to explain the various features of 'MASC' software. It is developed in MATLAB 2013a along with some java libraries whose functions are incorporated with the MATLAB code to enhance the look and field of the GUI and make it user friendly.

*Keywords* Band Calculator; Binary Image Formats; Expression Evaluator; gain and offset; MASC Software; MATLAB

## 1. Introduction

Remote Sensing is the science and art of obtaining information about an object or target without touching it. The images which are captured can be digital or analog. The analog images are mainly taken via aircraft associated with a sensor and the digital images are taken from satellites. A digital

image is a two-dimensional array of pixels. Each pixel has an intensity value (represented by a digital number) and a location address (referenced by its row and column numbers) [1].

The intensity value represents a physical quantity such as solar radiance, emitted infrared radiation or backscattered radar intensity. The intensity value is basically a digital number and the number of bits is the measure of the radiometric resolution of the image. For example, a 16-bit number ranges from 0 to 65535 (i.e. $2^{16}$ -1). The image band is two dimensional and the location address of the pixel is denoted by the row and column coordinates [1].

Image bands are a collection of images taken simultaneously of the same area in multiple regions of the electromagnetic spectrum. Human vision is able to detect three wavelengths: red, blue and green. All the colours that humans can perceive can be created by mixing these three colours [2].

Images can be displayed as grey scale images or colour composite images popularly known as False Colour Composite (FCC). Grey scale images comprise of only a single band whereas a FCC is a combination of three bands at a time. Associating each spectral band to a separate primary colour, results in a colour composite image. Colour composite images can be mainly of two types. First type of composite is known as **True Colour Composite**, which consists of three visual primary colour bands in such a way that the images resemble the original view. Second but commonly used composite is known as False Colour Composite (FCC) in which three bands are assigned arbitrary colours in such a manner that the image does not resemble the original view and is therefore known as False Colour Composite image [3].

Remote sensing data (images) acquired from various sensors and platforms have already proved its importance for the assessment, monitoring and management of natural resources in the entire globe. However, effective interpretation of remote sensing images acquired by space borne and air borne sensors requires various mathematical and statistical operations to be applied to them. Importance of use of various mathematical and statistical operations on Remote Sensing Images enhances manifold if the research/project work requires analysis of large number of Remote Sensing Images. A large number of commercial image processing software are available in the market to support the requirement of implementation of various Mathematical and Statistical operations on remote sensing images. However, in general, the cost of various commercial software are very high. Therefore, they may not be affordable by many schools and few institutes where sufficient funding is not available.

Looking at the requirement of a freely available image processing software to perform various mathematical and statistical operations on large number of remote sensing images or a multi-band image, a GUI based image processing software has been developed to help those who want to work and explore remote sensing data but doesn't have sufficient funds to purchase costly software. Based upon the objective of the software, the name of the software has been decided as MASC (Mathematical and Statistical Calculator). This paper is about 'MASC' GUI which performs operations similar to 'mathematical and statistical operations on various bands' tool of some of the commercially available software. These software are very useful in image enhancement and interpretation. The aim of this paper is to explain the various features of 'MASC' software. It is developed in MATLAB 2013 along with some java libraries whose functions are incorporated with the MATLAB code to enhance the look and field of the GUI and make it user friendly [4-5].

The 'MASC' software is developed to handle optical images of 8-bit, 16-bit, 32-bit and double data. If user wants to apply mathematical and/or statistical operations on multi-band remote sensing data, the input image files should be layer stacked with any number of bands, user can use any interleave format [6]. However, user is required to keep an associated '.hdr' file in the same folder where he is keeping the input image data. The input images are loaded into the GUI's central panel. These images can be grey scale or colour composite images (both true and false colour composite).

## 2. Conceptualization of MASC Software

This GUI will be used for better and effective interpretation of an image. It performs various arithmetic, exponential, logarithmic, trigonometric and statistical functions on image bands. When an image is taken it has a certain DN (digital number) value associated with each pixel. This DN value contains useful information about the target. Interpretation of single band remote sensing data is very easy but use of single band to extract useful/meaningful information about a target is not always possible. Therefore, it is a common practice in remote sensing to exploit multi-frequency or multi-temporal images of same area to extract detailed and meaningful/useful information about a target. However, interpretation of multi-band (multi-frequency and/or multi-temporal) remote sensing data is difficult, especially when number of input bands are more than three. In case of large number of input bands user needs to apply many mathematical and/or statistical operations on the set of images under consideration. Looking at the huge requirement of various mathematical and statistical operations on multi-band data "An Open Source Free Downloadable GUI Based Image Processing Software for Performing Various Mathematical and Statistical Operations on Remote Sensing Images" has been developed for the benefit of students of those schools where sufficient funding is not available. The software may also be useful for those researchers who are not getting scholarship or funding but willing to explore freely available remote sensing data. 'MASC' GUI which performs operations similar to 'mathematical operations on various bands' tool of some of the commercially available software, is also very useful in image enhancement and interpretation.

This GUI is built using MATLAB 2013a along with some java libraries whose functions and classes are incorporated with the MATLAB code to enhance the look and field of the GUI and make it user friendly [7]. MATLAB comes with a bunch of libraries which comprise of mathematical functions. Along with that MATLAB also has an image processing toolbox which makes working on images easier in comparison to other software [8-9]. In order to read and perform operations on optical images, MATLAB's 'ENVI file reader/writer' library is used [10-11].

In order to implement 'mathematical/statistical operations on various bands' tool, several mathematical/statistical functions have been used along with user defined functions. In addition to this, an expression evaluator algorithm has been developed which is capable of solving a valid mathematical/statistical expression on image bands and provides the output.

Along with 'mathematical/statistical operations on various bands' tool, this software also provides the user various other features like adjusting gain and offset values, pixel value display box, spatial sub setting and spectral profile in order to enhance user experience. These features shall be discussed further in detail.

## 3. Software Design

The name of the software is coined as 'MASC', which is abbreviation of 'Mathematical and Statistical Calculator'. Figure 1 shows the GUI with two opened images. At the top of the GUI is a menu bar followed by a toolbar. The tool bar consists of all the options present in the menu bar for the quick access of the user. Various shortcut keys have been provided to use the GUI tools effectively. The help option in the menu bar or 🔞 button in the toolbar provides all the necessary indications to use the 'MASC' software and information about the various components of 'MASC' software.
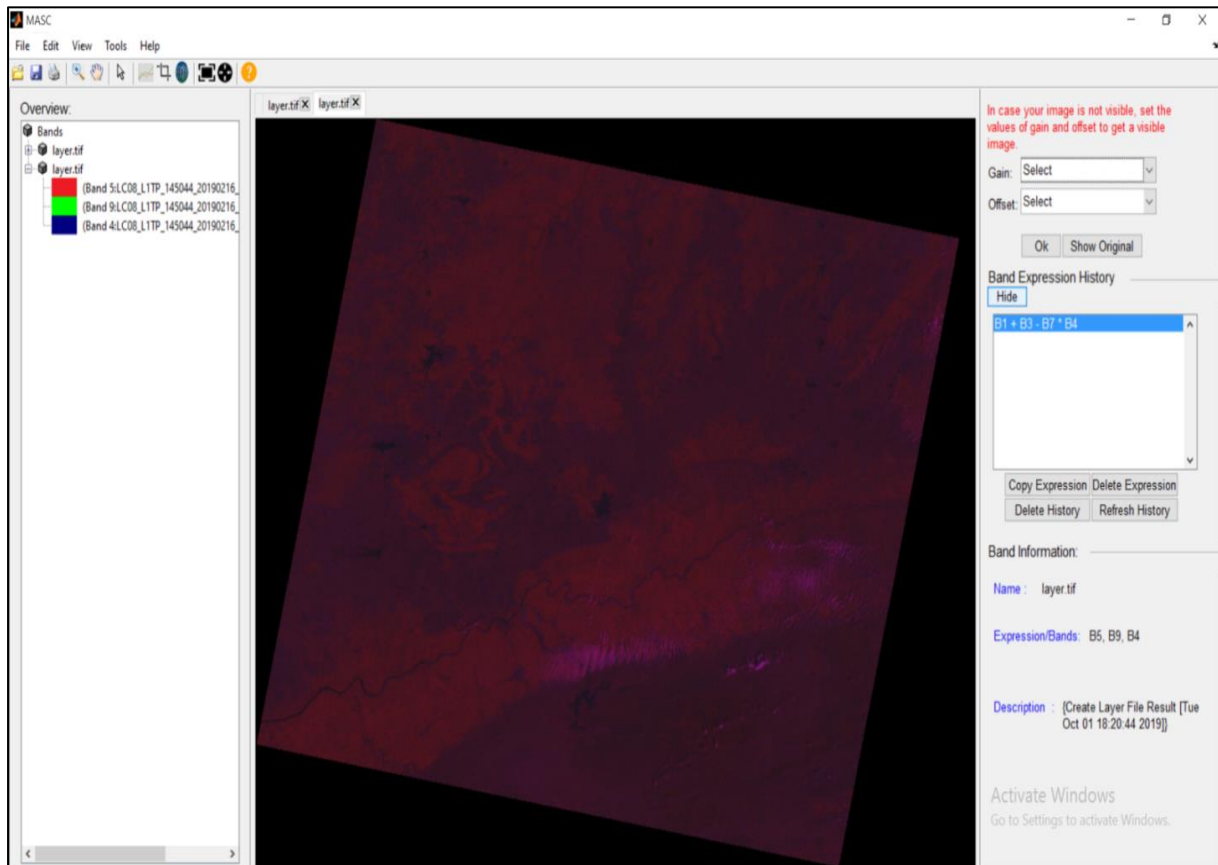
*Figure 1: GUI with two opened images*

Below the toolbar the GUI window is divided into three parts: the overview, the display panel and the panel which comprises of gain and offset option, the band expression history and the band information. The overview displays all the currently opened images in the central panel along with names of their respective bands. This is displayed in the form of a tree structure. The central panel is a java based tabbed panel where each new image opens in a new tab. The right panel is divided into following three parts (viz. the gain and offset, the band expression history and the band information)

3.1. **The gain and offset** adjusts the grey scale image level of brightness and contrast. The gain and offset values are obtained when the user selects them from the drop down list and clicks OK button. The gain value is multiplied to the image colour map and the offset value is added to it. Both gain and offset helps in balancing the brightness and contrast of an image without affecting the original pixel values of an image [12].

3.2. **The band expression history** helps in storing the saved band calculator expressions from the band calculator dialog box. Even after closing the GUI, the saved expressions remain in the band history. The user is given a choice to delete an expression, delete entire history, refresh history or copy an expression from the history to use it again.

3.3. **The band information displays** the current image name, the band number it is comprised of or the band expression it is formed of, the description of the band and the original band name if the band is a derived band. A band can be a derived band only in two scenarios: it is the output of a band calculator expression or it is the output of spatial sub setting of an image. This information changes as the user switches from one tab to other.

The GUI is very user friendly as it provides the user with the options of zoom, pan, save, open, print, fit to window and convert. These options help in analysing images in a better way. The information regarding the use of these tools is provided in the help.

The zoom option helps in zooming in or out of the image using mouse scroll. Clicking again on zoom will deactivate zoom option. The pan option helps in hovering over the zoomed in image wherever you want and works in a similar manner like zoom. The print option helps in printing the current image on the screen. Save option saves the image but does not create a '.hdr' file for the same. In order to view the image in the GUI its '.hdr' file should be present. For this the user is provided with the convert option in the file menu. This option allows the user to decide the interleave as well as the image format and creates a '.hdr' file for the image in the same folder in which the original image is present and saves it. This converted image can be opened in the GUI using its '.hdr' file.

The GUI displays error message wherever user tries to perform an invalid operation. For example, gain and offset is applicable only to grey scale image. If the user tries to perform gain and offset operation over an RGB image then an error message is displayed indicating invalid operation and notifying the user with the correct operation. Along with these features, this software also comprise of certain tools. Detailed description of various tools of MASC software is provided in next section.

## 4. Detailed Description of Various Tools Available with MASC Software

Although MASC software has essentially been designed to perform 'mathematical and statistical operations on various bands' of remote sensing images. However, in order to enhance the utility of MASC software for users, various additional tools have also been added in MASC software. These tools are (a) Band Calculator, (b) Cursor Value, (c) Spectral Profile, (d) Image Sub-setting, and (e) Converter. Additional tools like Cursor Value Tool, Spectral Profile Tool, Image Sub-setting Tool, and Converter Tool along with key tool of MASC software (i.e. Band Calculator Tool) make this software a complete package for basis analysis of temporal or multispectral Remote Sensing Images.

## 4.1. Band Calculator Tool

The band calculator tool comprise of various mathematical and statistical functions [13]. The user can open band calculator dialog box (Figure 2) from Tools->Band Calculator, or they can directly click on the icon on the tool bar. The user can also make use of the shortcut Ctrl + B.
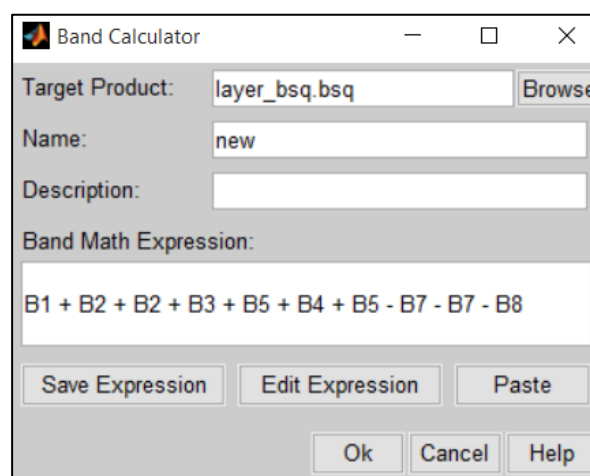


*Figure 2: Band Calculator dialog box*

After entering the required details, clicking on the edit expression will open the expression editor (Figure 3) as follows:
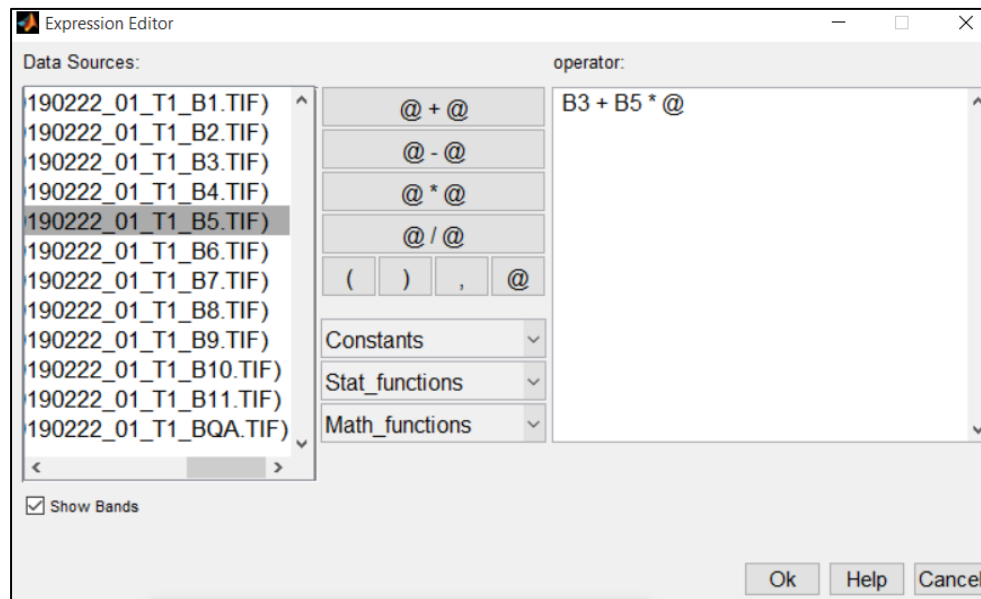


**Figure 3:** *Band Expression Editor*

The band expression editor is an expression generation tool that generates a band expression which will be evaluated further [13-16]. It is provided with a list of commonly used constants, statistical and mathematical functions along with all the basic arithmetic operators and special symbols. The help option displays a page which is an instruction manual for the users to understand the working of the editor. If a wrong expression has been formed, an error dialog box is displayed on the screen.

### 4.2. Cursor Value Tool

Simply opening the band calculator, writing the expression and getting the output will not give the surety that the user is getting the correct result. For this, the GUI is provided with a cursor value option which gives the pixel value of the current cursor position along with the pixel values of the neighboring pixels. The cursor value displays the pixel value of the current pixel rectangle. It is capable of displaying a single pixel value as well as the values of neighboring pixels.
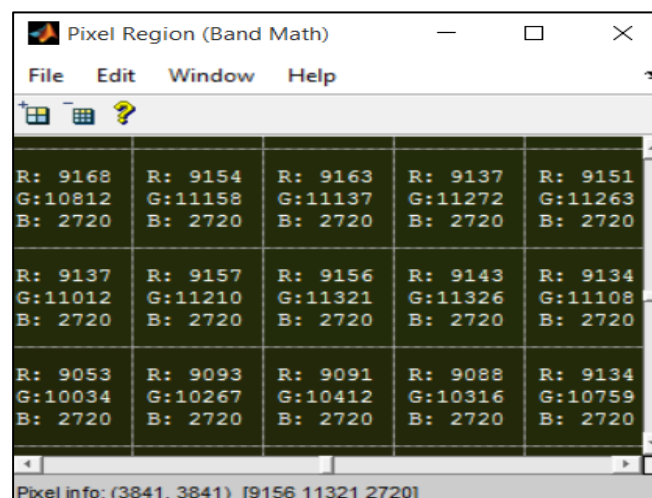


**Figure 4:** *Pixel Region Value Box*

The pixel region dialog box (Figure 4) displays the current rectangle pixel values and the bottom left corner displays the image coordinate along with the pixel values of the coordinate on which the cursor is pointing in the dialog. It displays the pixel values of RGB, grey scale and also 8-bit, 16-bit, 32-bit unsigned integer and also double values [17].

## 4.3. Image Sub Setting

The spatial sub setting of an image is possible with the help of image sub setter. The user can either directly select the subset area as shown in Figure 5(a) or he/she can enter the lines and sample range for sub setting as shown in Figure 5(b). The subsetted image will be displayed after clicking OK button.
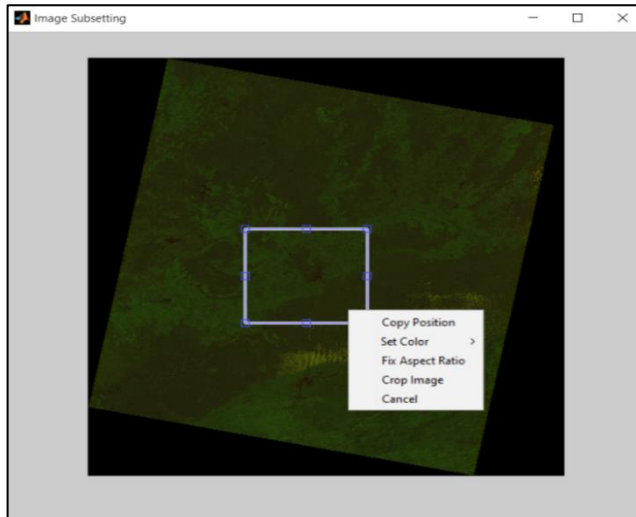


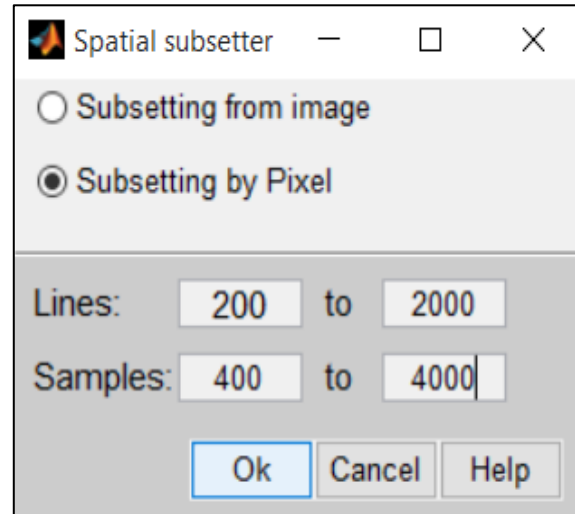**Figure 5(a)** *DirectSub setting from an image*          **Figure 5(b)** *Sub setting by pixel*

In 5(a) the user can drag using mouse the area he wants to select, right click and select crop. The area selected will be displayed in a new window. Whereas in 5(b), 'lines' is rows and 'samples' is columns. The user can set the range of lines and samples to get the image within this range. The subsetted image is displayed in a new tab. An error message is generated if the user inputs wrong data or the data which is not within range.

## 4.4. Spectral Profile Tool

The spectral profile (Figure 6) is a graph which is displayed for an image which is loaded into the GUI. The x-axis of the graph represents all the image bands in the image and the y-axis represents their corresponding pixel values.
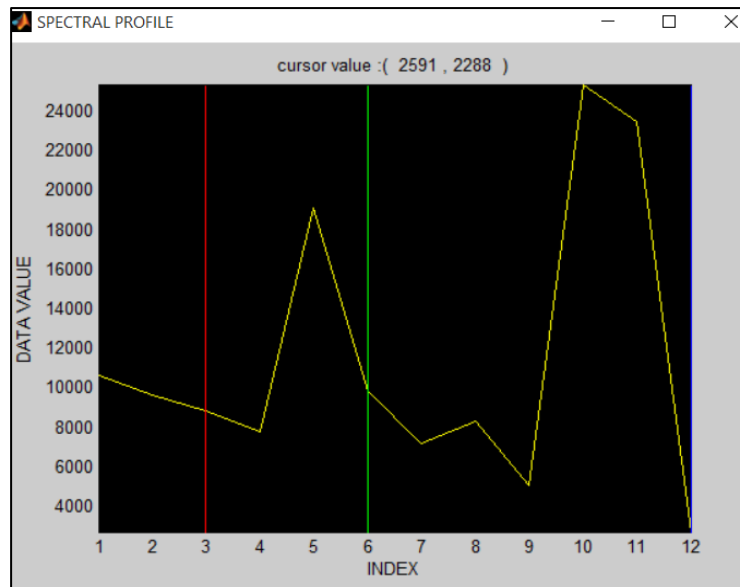
**Figure 6:** *Spectral Profile*

## 4.5. Converter Tool

The user can generate an image using image subsetter or band calculator and now he/she can save this image in his own binary and image format using the converter tool in the convert image dialog box (Figure 7). The user can give name to the file and this image will get stored in the required interleave and image format. The valid image formats are: .tif, .png, .jpg, .bsq, .bip and .bil.
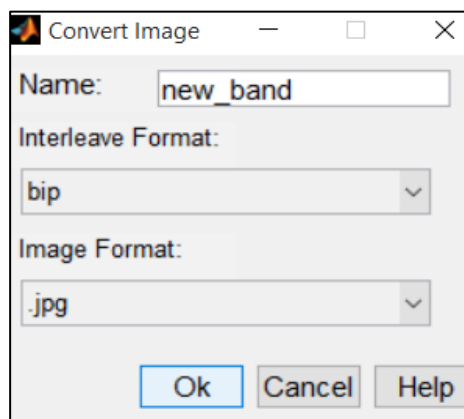


**Figure 7:** *Convert Image Dialog Box*

## 5. Opening an Image in GUI

When the software window loads onto the screen the first task is to open an image in the panel. The image should be an optical image along with a '.hdr' file. As the image appears, the tools and operations which can be applied on the image also appear on the toolbar. The '.hdr' file is a header file which contains information about the image like lines, samples, bands, band name, interleave format, etc. This information is fetched and the image is displayed as a 3-D matrix if RGB and a 2-D matrix if grey scale. Every image is stored inside the computer's memory in some binary format. This format cannot be displayed. It has to be converted into a matrix form for the viewer to see.

## 5.1. Binary Image Formats

This tool performs operations on optical image bands which consist on non-complex data. Basically there are three ways in which an image is stored in a binary format. They are namely: BSQ, BIL and BIP [18-19].

**BSQ:** It stands for Band Sequential. In this format the bands are stored one after the other. The first band will be stored first followed by the second and the third band.

**BIL:** It stands for Band Interleaved by Line. In this format the first line comprise of the first band. The second line comprises of the second band and the third line comprise of the third band. And this pattern is repeated till the end.

**BIP:** It stands for Band Interleaved by Pixel. As the name suggests, first pixel is the first pixel of the first band, second pixel is the first pixel of the second band third pixel is the first pixel of the third band and this pattern is repeated till the end.



BSQ, BIL and BIP are just storage formats and they don't disturb the basic arrangement of pixels in an image band. Therefore when the user wants to view the image, the R,G and B pixel values are fetched from the above and are stored as follows:



*Figure 8: RGB pixel values are stored in the form of a 3-D matrix*

This 3-D matrix of pixels is displayed on the screen.

## 6. Calculations performed by band calculator on images

On getting the expression using the band calculator expression editor in 'MASC' GUI the expression will be evaluated. Each band will be extracted in a 2-D matrix and the operations between two bands will be performed on each of the corresponding pixel in each band. The band expression b1+b2+b3 will be evaluated as shown in Figure 9 [20].
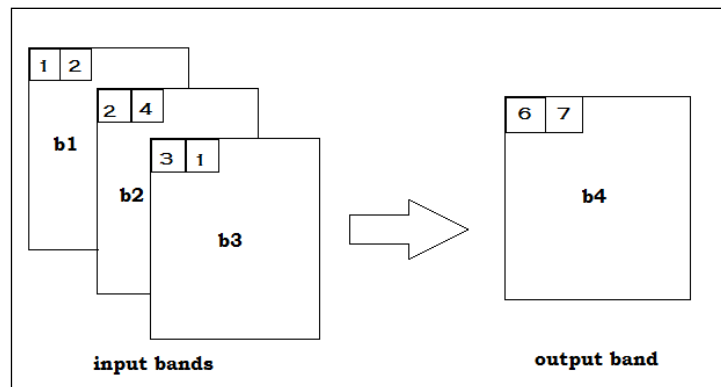


*Figure 9: Input and output bands after performing band operation b1+b2+b3*

Hence, all the corresponding pixels will be added together to give the new band b4 in the above example. The output will always be a grey scale image. The band calculator will similarly perform other mathematical and statistical operations on bands considering corresponding band values as operands.

## 6.1. Band Expression Evaluation Algorithm

The simple expressions can be evaluated using stack. But for evaluating band expressions which comprise of trigonometric and statistical functions, the simple expression evaluation algorithm needs to be expanded. This is possible with the help of stack in MATLAB 2013a. MATLAB performs operations on images. A simple addition operation can be performed on all the pixels of an image simultaneously. Thus, this feature of MATLAB avoids looping and reduces the time taken by the algorithm. This algorithm is implemented using stack [20-21].

A band expression can involve any size of data. For example:

B1 + B2 – B3 * 0.5

In the above expression, the band B1, B2 and B3 belong to the same image and hence have the same size, but the constant 0.5 is a single value which is to be multiplied with every element of B3. While implementing stack we usually prefer numerical arrays. But numerical arrays contain numerical scalars as elements. Therefore, it is impossible to store a different number of elements in different slices of same dimensions. Instead of using numerical arrays **MASC** uses cell arrays as they contain variables of any type and dimensions as elements.

Let us consider a sample expression:

tan( B1 + B2 ) + stddev( B1 , B2 , B3 )

| |
|---|
| + |
| tan( |
| ( |

( tan( B1 + B2)

| |
|---|
| |
| B2 |
| B1 |

| |
|---|
| |
| tan( |
| ( |

( tan( B1 + B2)

| |
|---|
| |
| |
| B1+B2 |

| |
|---|
| |
| |
| + |
| ( |

( tan( B1 + B2) +

| |
|---|
| |
| |
| |
| tan(B1+ B2) |

| |
|---|
| , |
| , |
| stddev( |
| + |
| ( |

( tan( B1 + B2)
+stddev(B1,B2,B3)

| |
|---|
| |
| B3 |
| B2 |
| B1 |
| tan( B1+B2) |

|  |
|---|
|  |
| + |
| ( |

( tan( B1 + B2)
+stddev(B1,B2,B3)

|  |
|---|
| stddev( B1,B2,B3) |
| tan( B1 + B2 ) |

|  |
|---|
| ( |

( tan( B1 + B2)
+stddev(B1,B2,B3) )

|  |
|---|
| tan(B1+B2)+ |
| stddev(B1.B2,B3) |

**Operator Stack**　　　　**Extracted Expression**　　　　**Value Stack**
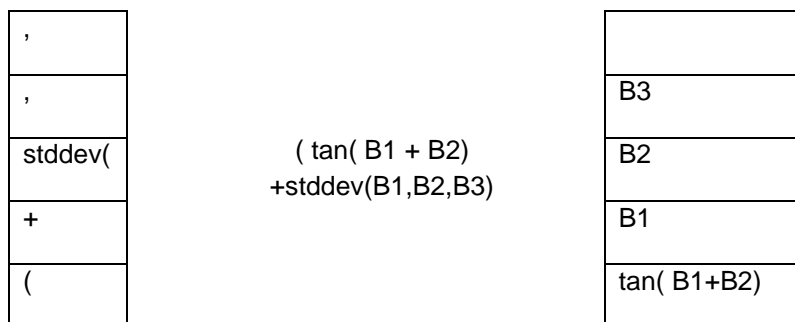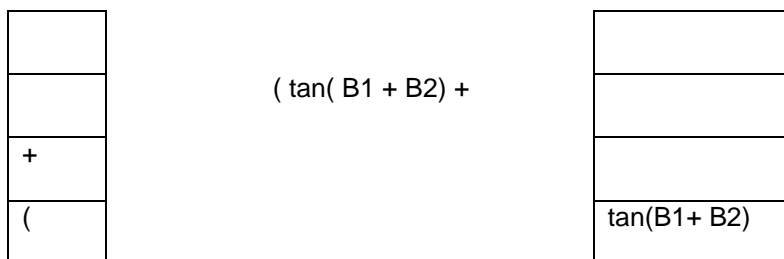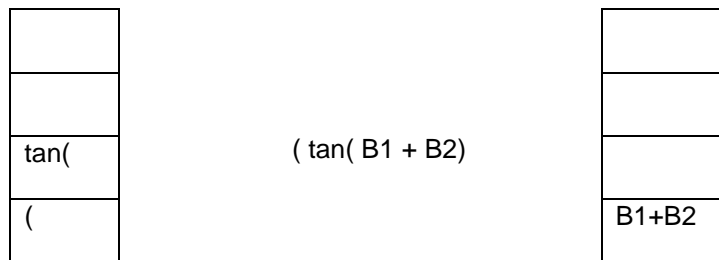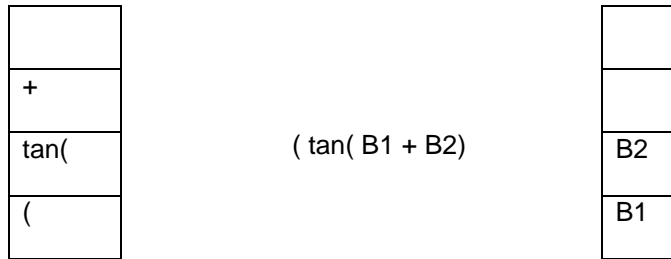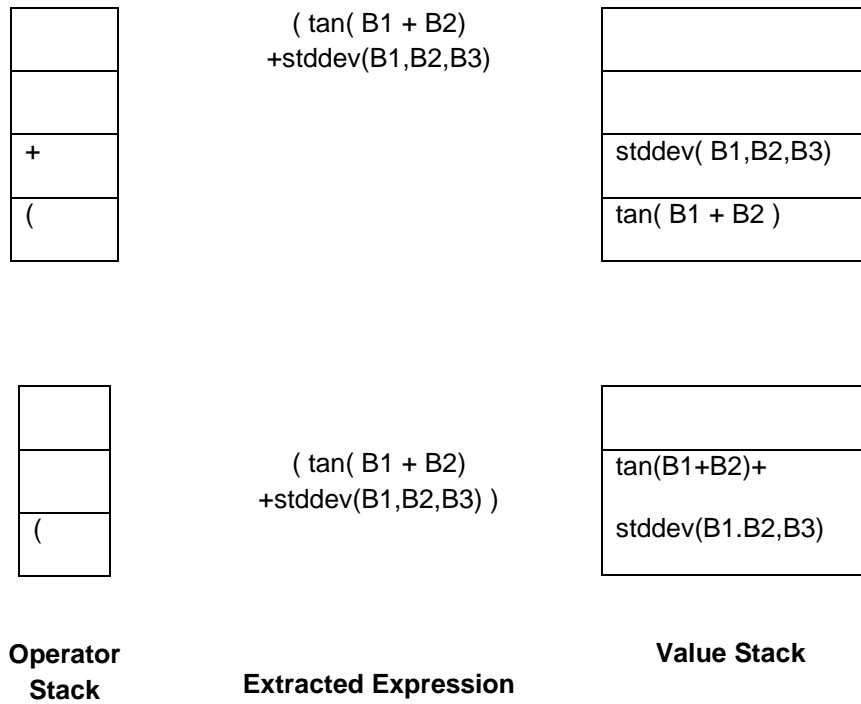
The band editor reads the expression as:

'(' 'tan('  'B1'  '+'  'B2'  ')'  '+'  'stddev('  'B1'  ','  'B2'  ','  'B3'  ')'  ')'

All the operators, functions, brackets and commas are pushed into the operator stack and all the variables and constants are pushed into the value stack and the expressions are evaluated according to the following order of precedence:

**Table 1:** *Operator/ Functions Precedence Table*

| Precedence Number | Operators/ Functions |
|---|---|
| 1. | (),statistical  functions ,mathematical functions |
| 2. | * , / |
| 3. | + , - |

## 7. Supported Operators and Functions

In MASC GUI, the following operators and functions will be supported for performing operations on image bands.

### 7.1. Arithmetic Operators

**Table 2:** *Arithmetic Operators in Band Calculator*

| Arithmetic Operator | Description |
|---|---|
| **+** | adding X and Y. If X and Y are image bands, every element of X will be added with every corresponding element of Y. If on adding the bands the result exceeds the given range then the value is divided by the maximum range value and brought within the range. If X is a band and Y is a constant then Y will be added to every element of X. Normal addition operation is performed if X and Y both are constants. |
| **-** | subtracting X and Y. If X and Y are image bands, every element of Y will be subtracted from every corresponding element of X. If on subtracting the bands the result is not within the given range then the value is divided by the maximum range value and brought within the range. If X is a band and Y is a constant then Y will be subtracted from every element of X. Normal subtraction operation is performed if X and Y both are constants. |
| **\*** | multiplying X and Y. If X and Y are image bands, every element of X will be multiplied with every corresponding element of Y. If on multiplying the bands the result exceeds the given range then the value is divided by the maximum range value and brought within the range. If X is a band and Y is a constant then Y will be multiplied to every element of X. Normal multiplication operation is performed if X and Y both are constants. |
| **/** | dividing X and Y. If X and Y are image bands, every element of X will be divided by every corresponding element of Y. If the divisor is zero then the dividend will not be divided. If X is a band and Y is a constant then Y will divide every element of X. Normal division operation is performed if X and Y both are constants. |

### 7.2. Mathematical Constants

Mainly two constant values can be used directly.

**PI= 3.14159265358979323846**
**E =2.7182818284590452354**

Some of the other constant values which are commonly used are also available like **0.5, 0.0, 1.0, 2.0, 273.15.**

Users can give their own constant values also by giving input from the keyboard.

### 7.3. Mathematical Functions

**Table 3:** *Mathematical Functions in Band Calculator*

| Mathematical Function | Description |
|---|---|
| **sqrt( X )** | Returns square root of *X* |
| **pow(X ,Y )** | *X* raised to the power of *Y* |
| **exp( X )** | Returns Euler's number *e* raised to the power of *X* |
| **exp10( X )** | Returns the value of *10* raised to the power of *X* |
| **log( X )** | Returns the natural logarithm (base *e*) of *X* |
| **log10( X )** | Returns the common logarithm, the logarithm with base 10 of *X* |
| **sin( X )** | Returns the trigonometric sine of an angle *X* in radians |
| **sinh( X )** | Returns the hyperbolic sine of an angle *X* in radians |

| | |
|---|---|
| **cos( X )** | Returns the trigonometric cosine of an angle $X$ in radians |
| **cosh( X )** | Returns the hyperbolic cosine of an angle $X$ in radians |
| **tan( X )** | Returns the trigonometric tangent of an angle $X$ in radians |
| **tanh( X )** | Returns the hyperbolic tangent of an angle $X$ in radians |
| **sech( X )** | Returns the hyperbolic secant of an angle $X$ in radians |
| **cosech(X )** | Returns the hyperbolic cosecant of an angle $X$ in radians |
| **rad( X )** | Converts X from decimal degree to radian |
| **deg( X )** | Converts X from radian to decimal degree |
| **abs( X )** | Returns the absolute value of X |
| **sign( X )** | Returns the sign of A, always one of -1, 0, +1 |
| **floor( X )** | Returns the largest (closest to positive infinity) double value that is less than or equal to X and is equal to a mathematical integer |
| **round( X )** | Returns the rounded value. |
| **ceil( X )** | Returns the smallest (closest to negative infinity) double value that is greater than or equal to X and is equal to a mathematical integer |
| **rint( X )** | Returns the double value that is closest in value to X and is equal to a mathematical integer. If two double values that are mathematical integers are equally close, the result is the integer value that is even |
| **nan( X )** | Returns true if X is a Not-a-Number (NaN) value, false otherwise |

## 7.4. Statistical Functions

*Table 4: Statistical Functions in Band Calculator [22-24]*

| Statistical Function | Description |
|---|---|
| **min( X , Y,…. )** | Returns the smallest of the elements provided as comma separated list. If a single value is present then the minimum of a 3x3 kernel is calculated for each pixel with all the surrounding pixel values equal to 0. [25] |
| **max( X , Y,…. )** | Returns the largest of the elements provided as comma separated list. If a single value is present then the maximum of a 3x3 kernel is calculated for each pixel with all the surrounding pixel values equal to 0. [26] |
| **stddev( X , Y , ...)** | Returns the standard deviation of the elements provided as comma separated list. If a single value is present then the standard deviation of a 3x3 kernel is calculated for each pixel with all the surrounding pixel values equal to 0. |
| **coef_var( X , Y , ...)** | Returns the coefficient of variation of the elements provided as comma separated list |
| **mean( X,Y,….)** | Returns the mean of all the elements provided as comma separated list |
| **kurtosis( X,Y,…)** | Returns the kurtosis of all the elements provided as comma separated list [27] |
| **skewness(X,Y,…)** | Returns the skewness of all the elements provided as comma separated list [28] |
| **meanabsdev(X,Y,…)** | Returns the meanabsdev of all the elements provided as comma separated list |
| **variance(X,Y,…)** | Returns the variance of all the elements provided as comma separated list. If a single value is present then the variance of a 3x3 kernel is calculated for each pixel with all the surrounding pixel values equal to 0. |

## 7.5. Formulae for the Statistical Functions

$$Mean = \overline{x} \ = \ \frac{1}{N} \sum_{j=0}^{N-1} x_j$$

$$Variance = \ \frac{1}{N-1} \sum_{j=0}^{N-1} (x_j - \overline{x})^2$$

$$StandardDeviation = \sqrt{Variance}$$

$$Skewness = \frac{1}{N}\sum_{j=0}^{N-1}\left(\frac{x_j - \overline{x}}{\sqrt{Variance}}\right)^3$$

$$Kurtosis = \frac{1}{N}\sum_{j=0}^{N-1}\left(\frac{x_j - \overline{x}}{\sqrt{Variance}}\right)^4 - 3$$

$$MeanAbsoluteDeviation = \frac{1}{N}\sum_{j=0}^{N-1}\left|x_j - \overline{x}\right|$$

$$CoefficientofVariation = \frac{StandardDeviation}{Mean}$$

## 8. Few Examples of Results Obtained for some Operations

Band Calculator is used to give results which are enhanced versions of original image in the form of a grey scale image. Following are few of the band calculator operation results:

### 8.1. Expression 1

**B1+B2+B3+B4+B5+B6+B7**

The above expression gives the following result for an image layer stacked (say) with 12 bands and adding the first 7 bands (Figure 10).
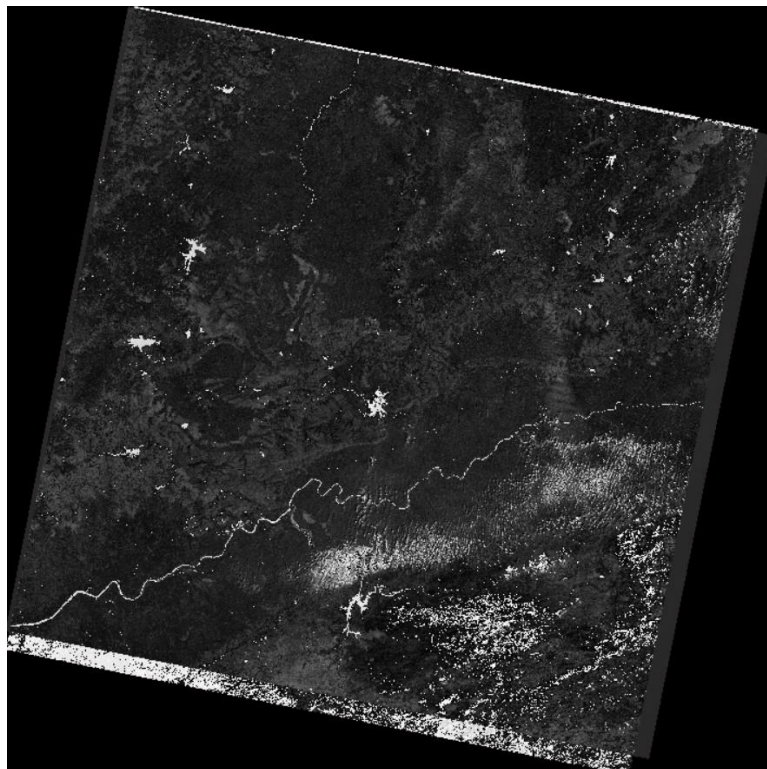


*Figure 10*: Result of Band Calculator expression B1+B2+B3+B4+B5+B6+B7

The pixel values at position let's say (3841, 3841) for bands are:

B1: 10799
B2: 9922
B3: 9156
B4: 8179
B5: 19399
B6: 11321
B7: 7890

Now addition is performed as follows:

Step 1: 10799+9922=20721
Step 2: 20721+9156=29877
Step 3: 29877+8179=38056
Step 4: 38056+19399=57455
Step 5: 57455+11321=3240
Step 6: 3240+7890=11130

Since the data we are adding is 16 bit data, in step 5, the addition of 57455 and 11321 gives 68776, this value is out of range as 16-bit data lie between 0 to $2^{16}$ and the highest 16-bit value is 65535. Since 68776 exceeds 65535 we take the modulus of 68776 by the total number of values in 16 bit data i.e. 65536 giving the remainder 3240 which is the desired value. This value is correct as the 16-bit data can only be within this range and taking the modulus will bring the exceeded value within range.

## 8.2. Expression 2

### B1+B3*2-B5/B8

The above expression will be solved according to the order of precedence (as mentioned in 8.1). Evaluating the expression gives the following result (Figure 11).
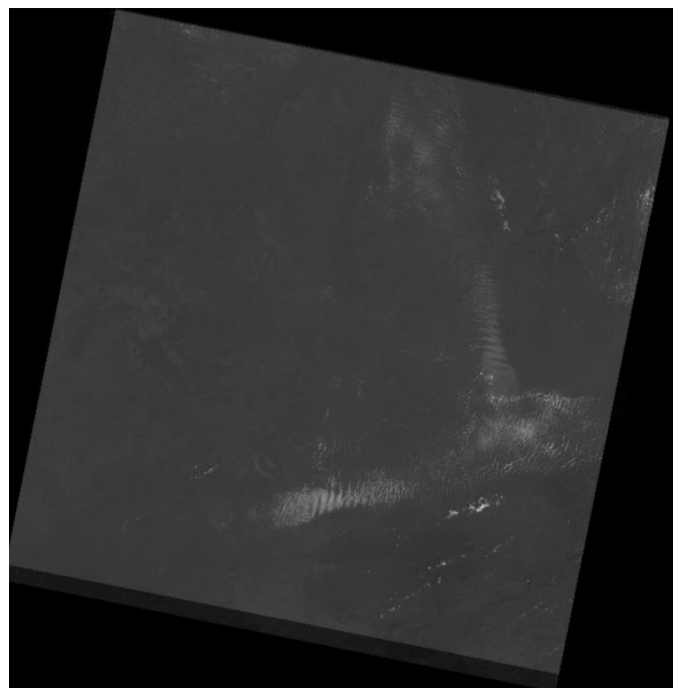


***Figure 11:*** *Result of Band Calculator expression B1+B3*2-B5/B8*

At position (3841, 3841)

Step 1: B3*2 → (9156*2=18312.0000)
Step 2: B5/B8 → (19399/8780=2) **(Note: Dividing 16-bit data will give only a 16-bit value)**
Step 3: B1+ (B3 *2) → (10799+18312=29111.0000)
Step 4: (B1 + (B3 * 2))-(B5/B8) → (29111-2=29109.0000)

Hence 29109.0000 is our answer which is a double value because constant 2 is multiplied to B3 and hence converts the entire expression to double.

## 8.3. Expression 3

**tan (b8)**

The band calculator can perform trigonometric operations as well. The tan of the pixel value gives the following result (Figure 12).



*Figure 12: Result of band calculator expression tan (B8)*

The output value at (3841, 3841) is which is the tan of value 8780 is -0.934339974512928. It first converts the 16-bit number to double and thereafter calculate its tan.

## 8.4. Expression 4

**stddev(B6)**

Standard deviation is defined as a quantity expressing by how much the members of a group differ from the mean value for the group. The standard deviation for several bands is calculated by finding

the standard deviation of the comma separated bands in the function stddev(). If standard deviation is calculated for single band, then the standard deviation of a 3*3 kernel is calculated with the target pixel being the central pixel. This 3*3 kernel is used for calculating the standard deviation of the entire image matrix. The border pixels of the matrix are set to 0.
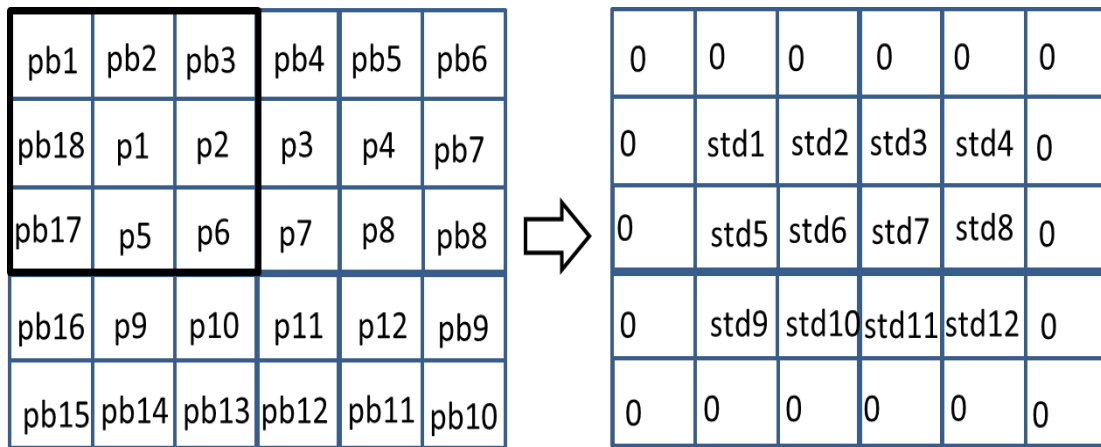
| pb1 | pb2 | pb3 | pb4 | pb5 | pb6 |
|-----|-----|-----|-----|-----|-----|
| pb18 | p1 | p2 | p3 | p4 | pb7 |
| pb17 | p5 | p6 | p7 | p8 | pb8 |
| pb16 | p9 | p10 | p11 | p12 | pb9 |
| pb15 | pb14 | pb13 | pb12 | pb11 | pb10 |

| 0 | 0 | 0 | 0 | 0 | 0 |
|---|---|---|---|---|---|
| 0 | std1 | std2 | std3 | std4 | 0 |
| 0 | std5 | std6 | std7 | std8 | 0 |
| 0 | std9 | std10 | std11 | std12 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 |

*Figure 13: standard deviation calculation for a single band*

This 3*3 kernel moves in the horizontal and vertical direction. The standard deviation value is set at the central position inside the kernel. In the above Figure 13 the currently selected kernel is indicated by black box and the value at p1 will be replaced by the standard deviation of the values within the kernel.

The following is the result for calculating the standard deviation for a single band (Figure 14).
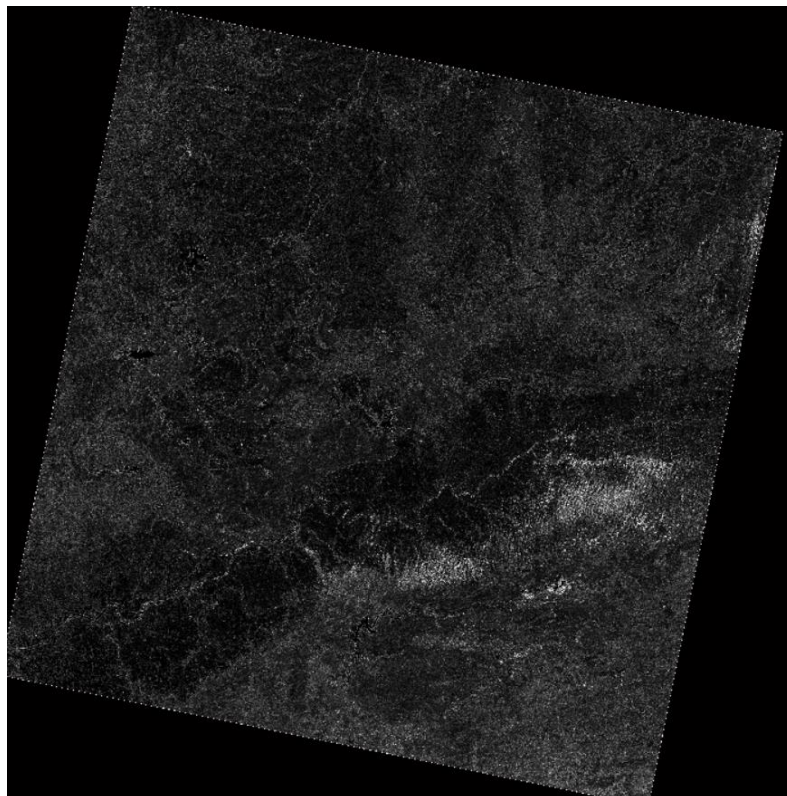


*Figure 14: Result of band calculator expression stddev(B6)*

The pixel dialog box for the band B6 for position (3841, 3841) being the central position in the kernel of 3*3 is as follows (Figure 15):

| 11158 | 11137 | 11272 |
| 11210 | 11321 | 11326 |
| 10267 | 10412 | 10316 |

*Figure 15: 3*3 kernel for position (3841, 3841) in band B6*

On calculating the standard deviation of this block we get the value 4.588731e+02 which is the desired pixel value we get at position (3841, 3841).

## 8.5. Expression 5

**Skewness (B4, B8, B5, B3)**

**Skewness** is defined as measure of the asymmetry of the probability distribution of a real-valued random variable about its mean. The skewness value can be positive, zero, negative, or undefined. The skewness of bands is calculated pixel by pixel in a similar manner. We have taken bands B4, B8, B5 and B3 of our layer stacked image and applied the skewness function to them. Skewness will be calculated for corresponding pixels of the 4 bands at each pixel position to give the final output as follows (Figure 16):
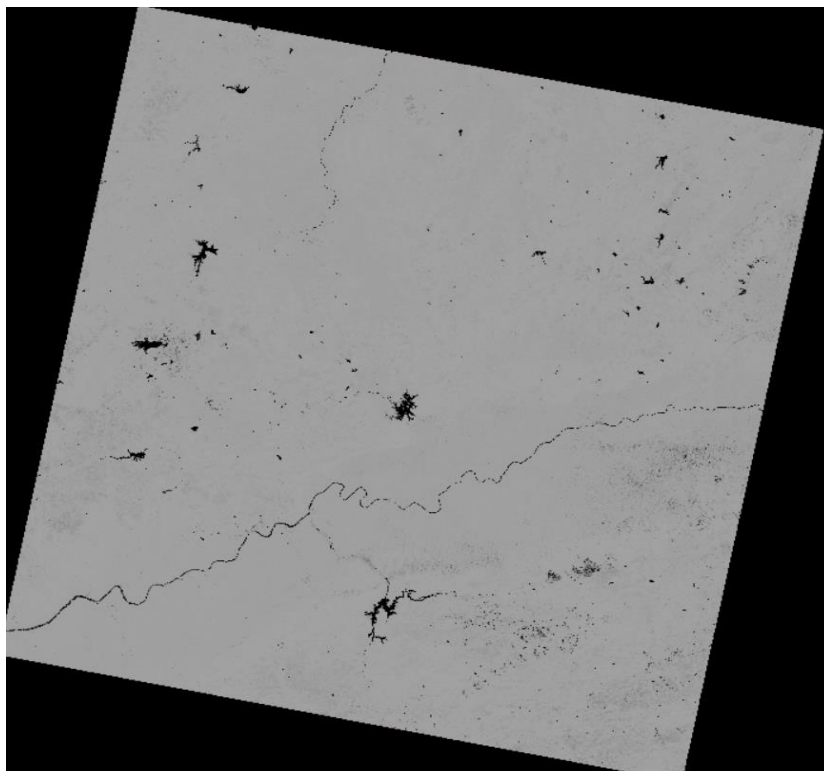


*Figure 16: Result of band calculator expression skewness (B4, B8, B5, B3)*

The result can be checked with the pixel value at sample position (3841, 3841) in the above image with the help of pixel evaluator. Hence, the skewness at this position is 1.134977957760603.

## 9. Conclusion

In this paper an attempt has been made to discuss various features of 'MASC' software along with its functioning. Paper explained the basic working of 'band calculator expression evaluator' algorithm and presented the results obtained by band calculator. The results obtained have been cross checked by the pixel evaluator which fetches the pixel value from the image on the screen. These values may be cross-verified by a user with the expected values to be obtained as results. Besides 'band calculator', paper also highlighted other features of 'MASC' software which make the software user friendly and more robust. Authors expect that this paper will be able to boost users' interest in open source free downloadable GUI based 'MASC' Image Processing Software for performing various mathematical and statistical operations on multi-temporal and multi-spectral remote sensing images. Availability of 'MASC' Image Processing Software will be very useful for students of those schools, colleges and institutes where sufficient funding is not available, but students wish to work with freely available multi-temporal and multi-spectral remote sensing images acquired by various satellites. It is expected that proper utilization of various tools of 'MASC' software will certainly enhance students' understanding about remote sensing data by providing option for better interpretation of multi-temporal and multi-spectral remote sensing images. **The exe file of the software can be obtained by sending an email to masc.freeware@gmail.com**. A *.EXE downloadable file will be send to the interested student/researcher. Any queries, suggestions and feedbacks can also discussed by sending an email to masc.freeware@gmail.com.

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