G: IMPROVED COASTAL IMAGES

Like *Frequently Asked Questions*, a question is posed, e.g., *G1. How Do Images of Water Differ from Images of Land?* Then, an answer is given[1] with comments and opinions. The items are labeled, e.g., *G1*, for referencing.

This tutorial deals with WATER.sml and FILTER_WATER.sml, their uses, and their options.

WATER.sml produces an IMAGE raster that is a merged combination of an enhanced water picture and a reference land picture. IMAGE is a single 24-bit color RGB raster that can be exported to an external file, e.g., a single GeoTIFF file, as a value-added image product. This script is based on recently published ideas by the author (Paris, 2005).

WATER.sml requires the following input data:

- A set of four SRFI rasters (from SRFI.sml), namely, SRFIBL, SRFIGL, SRFIRL, and SRFINA.
- A binary WATERMASK raster that designates water pixels by the value 1 and land pixels by the value 0.

WATER.sml includes an option that creates a new WATERMASK raster. Otherwise, the script needs to have a pre-existing WATERMASK raster. A companion script, called FILTER_WATERMASK.sml, can be used to improve the quality of the WATERMASK raster that is produced by WATER.sml. Also, you can improve the quality of the WATERMASK raster by using the TNTmips Spatial Data Editor tool, especially with its Flood Fill option. With these options, you can produce a high-quality, complex merged IMAGE raster like the one below (based on QuickBird MS data processed by WATER.sml).

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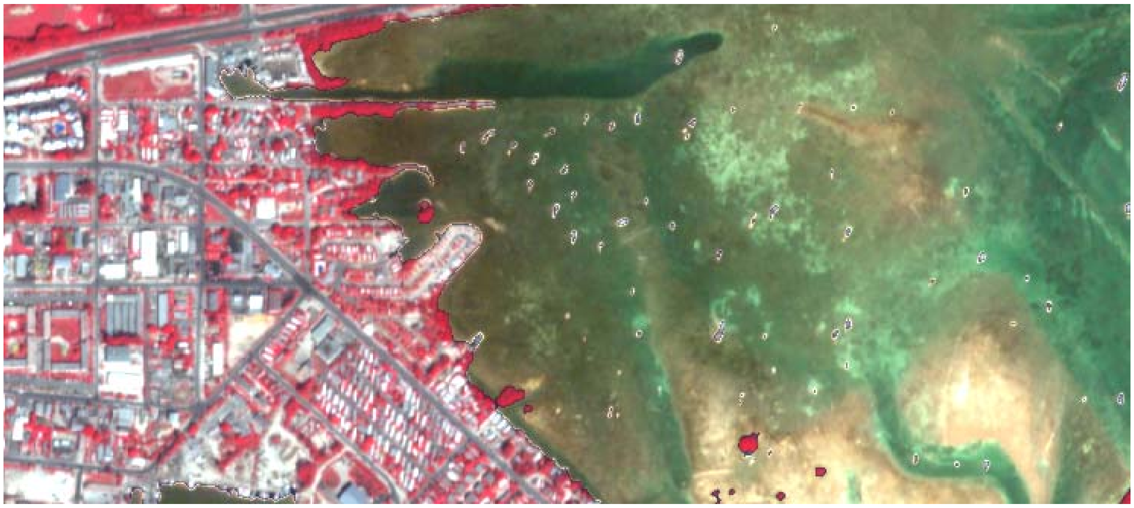

In Brief …

This tutorial discusses key SML functions and model concepts related to **WATER.sml**. The list below is divided into two groups: one for the key SML functions and the other for key model concepts.

If you are interested in a particular topic below, please go directly to it.

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Quick Guide to Using WATER.sml …

If you are already familiar with SML functions and syntax … and you just want to Run WATER.sml, this Quick Guide will help you.

BEFORE you run WATER.sml …

- Run SRFI.sml to produce the SRFI rasters that WATER.sml requires as input.

AFTER you start the script, the script will ask you to provide or to accept specific information items via a series of **Popup Windows**. The order of these will vary in response to the options that you choose. In the list below, all Popup options are included whether or not you actually will see them in a specific run.

- **CONSOLE-WINDOW ADJUSTMENT:** Use your mouse to adjust the size and placement of the Console Window. You need to be able to view its contents as the script runs and prints data to it. With TNTmips Version 7.1, you need make this adjustment only the first time you use SML.
- **VERSION / PATCH ENTRY:** If you are running an older version of TNTmips 7.1, the order of the primary colors (RGB) differs from that before the July 13, 2005, PATCH. Answer the query accordingly.
- **APPLY DEFAULT ENHANCEMENTS:** WATER.sml has up to 6 image enhancement parameters: redderW, brighterW, brightenDarkW, redderL, brighterL, and brightenDarkL (see below). At this point in the script, you can simply direct WATER.sml to use default values of these parameters. If you answer, "Yes," then you will not be asked to possibly change or accept these parameters. If you answer, "No," then you will be given an opportunity to change some or all of the enhancement parameters (or accept them one by one).
- **WATER-MASK OPTION ENTRY:** WATER.sml can (1) "Create a NEW WATERMASK Raster" or (2) "Use an EXISTING WATERMASK Raster." The first time that you use WATER.sml, you must select Option 1. After that, you can use the WATERMASK raster that you have created, whether you have improved it or not through you actions taken after the 1st run.
- **LAND-IMAGE OPTION ENTRY:** Select one of the 4 options.
- **REDDER-WATER-COLORS PARAMETER ENTRY:** Increase the value of redderW (above its default value of 1.18) to make the color of water features redder (less blue). Decrease its value to make the color of water features bluer (less red). Overall brightness is not affected by this parameter.
- **BRIGHTER-WATER-COLORS PARAMETER ENTRY:** Increase the value of brighterW (above its default value of 1.00) to make all water features brighter. Decrease it to make all water features darker.
- **BRIGHTEN-DARK-WATER-COLORS PARAMETER ENTRY:** Increase the value of brightenDarkW (above its default value of 1.43) to make dark water features brighter while not affecting the brightness of light water features.

- **REDDER-LAND-COLORS PARAMETER ENTRY:** Increase the value of redderL (above its default value of 0.95) to make the color of land features redder (less blue). Decrease its value to make the color of land features bluer (less red). Overall brightness is not affected by this parameter. If you have chosen to represent land by grayscale tones, you will not be asked to provide a value for redderL.
- **BRIGHTER-LAND-COLORS PARAMETER ENTRY:** Increase the value of brighterL (above its default value of 1.00) to make all land features brighter. Decrease it to make all land features darker.
- **BRIGHTEN-DARK-LAND-COLORS PARAMETER ENTRY:** Increase the value of brightenDarkL (above its default value of 1.25) to make dark land features brighter while not affecting the brightness of light land features.
- **SELECT RASTER OBJECTS FOR SRFIBL, SRFUGL, SRFIRL, and SRFINA:** Navigate to the location of these rasters and select them.
- **SELECT WATERMASK Raster:** Either select an existing WATERMASK raster or designate the location for a new WATERMASK raster.
- **SELECT IMAGE Raster:** Navigate to a location for the new IMAGE raster. You should add to its default name to designate the type of land representation that you selected, e.g., IMAGE_CIR, IMAGE_NC, IMAGE_GRAYgreen, or IMAGE_GRAYnir. The script will run to completion. It writes the values of key control parameters and related parameters to the Console Window.
- **SAVE THE CONTENTS OF THE CONSOLE WINDOW:** Right-Click in the CONSOLE WINDOW and use SAVE AS… to save its contents as a WATER_Report (.txt added automatically).

Quick Guide to Using FILTER_WATERMASK.sml …

- Run FILTER_WATERMASK.sml. This is a script that has few inputs and outputs.
- **CONSOLE-WINDOW ADJUSTMENT:** Use your mouse to adjust the size and placement of the Console Window. You need to be able to view its contents as the script runs and prints data to it. With TNTmips Version 7.1, you need make this adjustment only the first time you use SML.
- **WARNING:** Take note of the fact that the source raster, WATERMASK, will be **irreversibly** changed by FILTER_WATERMASK.sml. It is recommended that you use a copy of the WATERMASK raster with this script.
- **SELECT a WATERMASK Raster (to Process):** Navigate to the desired input (and output) raster and select it. The program runs to completion. You may want to save the report in the Console Window. It shows how many water pixels got converted to land pixels during each loop of the script.

G1. How Do Images of Water Differ from Images of Land?

Most four-band multispectral (MS) georeferenced colorized image products focus on presenting land features, such as vegetation, soils, rocks, and a variety of man-made materials, as natural or false-color infrared pictures. In most cases, color images of land features are presented as natural color (NC) or as false-color infrared (CIR) products. While water features are often present in these colorized land images, the related colors are usually too dark and have hues that are too blue or too green.

Consider typical colorized images of coastal water and land features in a DigitalGlobe QuickBird MS picture taken of a portion of Stock Island, FL (east of Key West, FL) on November 7, 2004. Figure G1A shows a typical *land-optimized* NC image. While the color and brightness of the land features are good in this image, the water features are too dark. Figure G1B shows the same area as a *water-optimized* NC image. While the water features look better, the land features are much too bright. In a like manner, *Figure G1C* shows a typical land-optimized CIR image while *Figure G1D* shows a typical water-optimized CIR image. Thus, manipulating contrast, brightness, and hue alone cannot create a single image that is suitable for land *and* water.

Figure G1A. Land-Optimized NC

Figure G1B. Water-Optimized NC

Figure G1C. Land-Optimized CIR

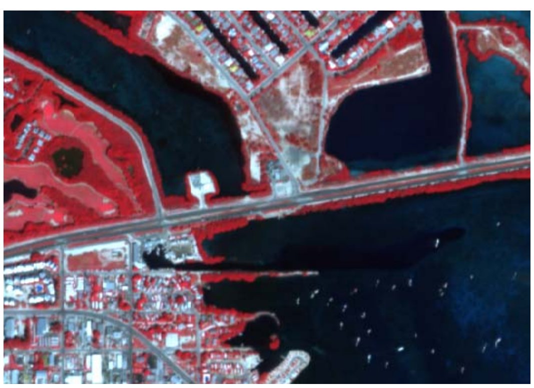
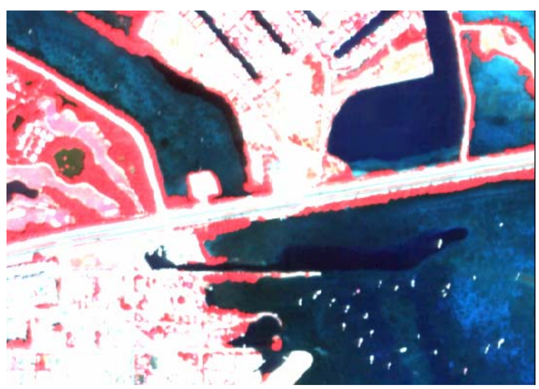


Figure G1D. Water-Optimized CIR



Even for the water-optimized images, the submerged water features still have distinctly blue and green colors. This is caused by strong absorption by water in the red light and near infrared bands. Altering the color balance of the water-optimized NC image towards red would reveal truly reddish features of submerged objects, e.g., sea grass. *Figure G1F* shows the effects of this kind of modification. Compare to *Figure G1E*, which is a copy of *Figure G1B*.

Figure G1E. Water-Optimized NC

Figure G1F. Water-Optimized NC with the Color Balance to Shifted to Reds

G2. Can I use TNTmips to Make a Merged Color Product that is Optimal for Both Land and Water Features?

Yes … but this requires that *you* manually use many TNTmips tools and processes, as follows:

1. Import a set of four spectral-band images from a suitable source as BL, GL, RL, and NA rasters. This has to be done no matter what.
2. From these source-image rasters, manually produce a binary raster, called WATERMASK. In this mask, water pixels = 1, and land pixels = 0.
3. From the WATERMASK raster, make a LANDMASK raster that sets land pixels = 1 and water pixels = 0.
4. Manually design a set of 3 contrast lookup tables (CLUTs) that optimize the display of land features as a RGB image. You have at least four basic options for representing the color of land pixels:
   - CIR: [R G B][2] = [Enhanced_NA Enhanced_RL Enhanced_GL]
   - NC: [R G B] = [Enhanced_RL Enhanced_GL Enhanced_BL]
   - GL-Gray: [R G B] = [Enhanced_GL Enhanced_GL Enhanced_GL]
   - NA-Gray: [R G B] = [Enhanced_NA Enhanced_NA Enhanced_NA]

[2] [R G B] stands for the Red phosphor's intensity, the Green phosphor's intensity, and the Blue phosphor's intensity on your color monitor. [R G B] *does not* stand for the physical brightnesses of the scene in the respective spectral bands, which are called RL, GL, and BL in *Scripts by Jack™*. In some remote-sensing discussions, this distinction is not clear; this leads to confusion.

5. Manually design a set of 3 CLUTs that optimize the display of water features as a RGB image. Water NC is the only choice that makes sense.
    - Water NC: R G B = Enhanced_RL2 Enhanced_GL2 Enhanced_BL2
6. Manually apply each CLUT to its related BL, GL, RL, and NA raster. This makes 6 numerically-modified color-component rasters, e.g.: Land_R, Land_G, Land_B, Water_R, Water_G, and Water_B (0 to 255 range).
7. Manually multiply Land_R, Land_G, and Land_B by the LANDMASK raster to create MaskedLand_R, MaskedLand_G, and MaskedLand_B.
8. Manually multiply Water_R, Water_G, and Water_B by the WATERMASK raster to create MaskedWater_R, MaskedWater_G, and MaskedWater_B.
9. Manually add MaskedLand_R to MaskedWater_R to make the Image_R raster.
10. Manually add MaskedLand_G to MaskedWater_G to make the Image_G raster.
11. Manually add MaskedLand_B to MaskedWater_B to make the Image_B raster.
12. Manually convert Image_R, Image_G, and Image_B as a set of RGB rasters to a 24-bit color RGB raster called IMAGE (set Contrast = None).

If you do not like the resulting colors, contrasts, and brightnesses in the final product, IMAGE, you would have to manually redo Steps 4 through 12 (over and over again, perhaps) until you are happy with the final IMAGE raster product!

This involves a lot of manual processing steps that you would have to carry out, without any errors, as you try to make the final IMAGE raster product!

WATER.sml script combines all of the processes above into a single process that:

- Enables you to create a necessary binary raster, called WATERMASK (needs to be done only once per source image). WATER.sml performs a classification process based on source imagery pixels (represented by SRFIBL and SRFINA). You must use SRFI.sml to produce SRFI rasters (referenced to the surface). The WATERMASK production process in WATER.sml uses a simple rule that you control by varying one or both of two control parameters.[3]
- Enables you to iteratively apply the equivalent of Steps 3 through 11 under SML script control. So, you can quickly produce an optimal final IMAGE product.

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[3] Using another script, called FILTER_WATERMASK.sml, you can clean up the WATERMASK raster from WATER.sml so that you can easily make simple modifications using the Flood-Fill option in the TNTmips Spatial Data (Raster) Editor.

- Also, WATER.sml suggests a set of default image enhancement parameters that are applied to input calibrated SRFI rasters (rather than to uncalibrated image raster DNs) to produce land and water colors that can be merged into a single 24-bit color RGB raster.
- You may, if you wish, alter any or all of the 6 enhancement parameters to change the appearance of the image in the following ways:
  - For the water pixels in the IMAGE raster, there are 3 parameters:
    - redderW: Make water-pixel colors redder.
    - brighterW: Make all water-pixel colors brighter.
    - brightenDarkW: Make dark-water-pixel colors brighter (while not affecting bright pixels).
  - For the land pixels in the IMAGE raster, there are 3 more parameters:
    - redderL: Make land-pixel colors redder (no effect when land-pixels are gray).
    - brighterL: Make all land-pixel colors (or gray tones) brighter.
    - brightenDarkL: Make dark-land-pixel colors or gray tones brighter (while not affecting bright pixels).

G3. How Can I Make the Required WATERMASK Raster?

The first time you use WATER.sml, you select the Create a NEW WATERMASK Raster Option 1. After that, select the default Option 2. It reuses an existing WATERMASK raster. Option 2 allows you to experiment with the values of the 6 enhancement parameters to achieve the best looking IMAGE product.

When you opt to make a NEW WATERMASK raster (Option 1), WATER.sml will ask you to provide 2 related control parameters: facBL and offNA.

- facBL: This is the LINE-EQUATION MULTIPLIER factor
- offNA: This is the LINE-EQUATION SRFINA-OFFSET parameter

The default values for these are facBL = 0.16 and offNA = 925.

You can (and probably should) change one or both of these parameters to produce an improved WATERMASK raster. You can evaluate the "goodness" of this raster by comparing the initial IMAGE product (with default enhancement options) to a standard reference image, such as a CIR image based on [R G B] = [SRIFNA SRFIRL SRFIGL]. SRFI rasters have contrast lookup tables that are designed to display land features well.

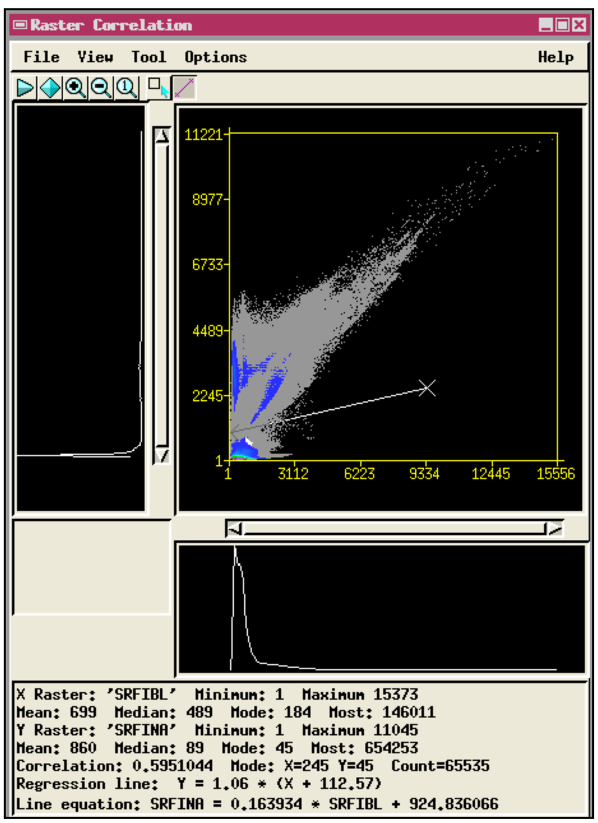
facBL and offNA are related to the LINE EQUATION tool in the Raster Correlation process.

So, you need to know how to use this tool.

Using the Raster Correlation tool:

1. First, use Display Spatial Data process to display a CIR image (Add RGB Rasters…) in a New 2D Group. Assign SRFINA, SRFIRL, and SRFIGL rasters (referenced to the surface), to Red, Green, and Blue, respectively.
2. It is fairly easy to distinguish water pixels from land pixels in a CIR image.
3. Next, click the Tools **icon** on this raster's layer in the Group Controls box.
4. Then, select Raster Correlation (from the dropdown list). The Raster Correlation tool appears with a default scatterplot of SRFIRL vs. SRFINA and with default colors that indicate the density of the data cloud.
5. NOTE: The default colors for this tool in Version 7.1 came from the author. They are ideal for evaluating the structure of data in a 2-Space plot. **Black** shows that no data exists. **Gray** shows where the density of the data is the lowest. Colors from blue, to cyan, to green, to yellow, and to red show increasing densities of the data cloud.
6. Next, you need to change the X Axis and Y Axis assignments in order to produce a new scatterplot of SRFINA vs. SRFIBL.
7. To change the X Axis and Y Axis assignments, click File, then click New.
8. Assign SRFIBL to the X Axis, and assign SRFINA to the Y Axis. A scatterplot of SRFINA vs. SRFIBL will appear (similar to *Figure G3*).

Figure G3. Scatterplot and Line Equation in the Raster Correlation tool.



The related Stock Island (FL) QuickBird scene has a lot of water pixels in it. Thus, the highest concentrations (shown as cyan and other non-blue and non-gray colors) of this 2-Space plot are for very low values of SRFINA matched by low to medium values of SRFIBL. The concentration of pixels having high SRFINA values and low SRFIBL values are green vegetation. Urban materials have SRFINA values that are similar to SRFIBL values, i.e., the blue concentration near the diagonal of this scatterplot.

The grayish Line equation divides the scatterplot into two domains – one for land pixels (above the line) and the other for water pixels (below the line).

9. When you move your mouse cursor around in the CIR image, you will see white colors dance around in the scatterplot. These white colors (see *Figure G3*) are called dancing points. They show how the raster values in image pixels near the mouse cursor plot over into the 2-Space plot represented by the scatterplot in the Raster Correlation tool.
10. IF the dancing points do not appear, try fixing this problem as follows:
    a. Close all running programs including email, Web browsers, and TNTmips.
    b. Re-launch TNTmips.
    c. Repeat Steps 1 through 9 above.
    d. If this still does not work, try shutting down your computer and re-booting from a power-off status. The dancing points feature uses lots of memory – and available memory may in short supply due to the needs of other software running on your computer.
11. Stretch out a grayish line (called the Line equation) in the scatterplot. You do this by holding down the left mouse button and rolling the cursor to another point. When you release this line, you can move its ends by moving the cursor close to one of the ends, holding down the left mouse button, and dragging it to a new position. Alternatively, you can use your cursor arrow keys to move one end or the other (selected by your mouse).
12. Position the Line equation such that it separates land pixels (above the grayish line) from water pixels (below the grayish line). See *Figure G3*.
13. Note the **coefficients** of the Line equation as shown at the bottom of the Raster Correlation window. In the example in *Figure G3*, the Line equation is defined by:

    SRFINA = 0.163934 * SRFIBL + 924.836066

10. So, facBL = 0.163934, which, rounded off, is about 0.16.
11. And, offNA = 924.836066, which, rounded off, is about 925.

For every pixel, the WATERMASK creation algorithm in WATER.sml tests the value of y = SRFINA against the value of yt = **facBL * SRFIBL + offNA**.

If **y > yt**, then the related pixel in the WATERMASK raster is assigned a value of **0** (LAND); otherwise, it is assigned to a value of **1** (WATER).

G4. Why Are There Four Options for Representing Land Pixels?

In a merged product like IMAGE, it is best to use one type of color to represent water (e.g., enhanced natural colors), and to use another type of color to represent land (e.g., color infrared, natural color, or a set of grayscale tones based on one spectral band image).

IMAGE always uses enhanced natural color to represent water pixels. But, you have four options for representing land pixels.

In the opinion of the author, the best representation of land pixels is the use of grayscale tones based on the near infrared (NIR) band image. Most non-water features are relatively bright in the NIR. This option (Option 4) is the default option in WATER.sml.

A possible objection to using NIR as the basis for land grayscale tones is that it does not look like historic panchromatic imagery. Option 3 uses the SRFIGL image as the source of grayscale tones for land pixels. While this looks like historic panchromatic, there are land features, especially vegetation, that are very dark in the GL.

Option 2 uses Natural Color (NC) for land pixels. Usually, land features have different NC colors than water features. But, the use of NC for both land and water can be confusing in a merged image like IMAGE.

Option 1 lets you pick CIR for land pixels. In the opinion of the author, this is the second best option (after Option 4) for representing land features. Land CIR false-colors are quite different than NC colors for water.

G5. What is the Effect of Increasing the Parameter, redderW?

Natural-color water features are seldom red. This is due to the strong absorption of red light by water. Thus, blues, cyans, greens, and yellows dominate the natural color of water and any visible submerged features.

The default value for redderW in WATER.sml is 1.18. If this value were set equal to 1.00, water features would be quite bluish in the IMAGE raster. This value for redderW causes the contrast enhancement of SRFIRL, SRFIGL, and SRFIBL to be the same in terms of relative percent reflectance factors. Sunlight and skylight illuminate water features. But, sunlight and skylight are more intense in the BL band than in the RL band. So, natural illumination causes water features to be even more blue than the reflectance factors would dictate! Therefore, the default value for redderW is set equal to 1.18 to compensate for the tendency of water features to be more reflective in the blue and for the fact that sunlight and skylight are stronger in the blue than in the red.

If you want the water features to have a greater bias towards red colors, then increase redderW to values higher than 1.18.

The algorithm that changes the color balance in response to changes in redderW has no affect on the green phosphor intensity of the water feature. But, the blue phosphor intensity is reduced while the red phosphor intensity is increased. The amount of decrease and increase is proportional to the difference between the wavelengths (normalized by the average wavelength of two spectral bands involved in this enhancement). This algorithm is arbitrary; but, it treats color shifts in ways that account for the actual wavelengths of the spectral bands involved.

G6. Okay, Why is the Default Value of redderL Equal to 0.95?

Natural-color land features are seldom blue. This is due to the strong absorption of blue light by many of land materials. Thus, reds, yellows, greens, and cyans dominate the natural color of land features.

To compensate slightly for the red-bias of natural color land features, the default value for redderW is set equal to 0.95. If this value were set equal to 1.00, land features would be too red in the IMAGE raster. This is true whether you are using natural color for land features or false-color infrared (CIR).

If you want the land features to have a *greater* bias in favor of red colors, then increase the value of redderL to values higher than 0.95.

If land features are being displayed as grayscale tones, then the value of redderL is irrelevant. In this case, you are not asked to select a value for redderL.

G7. What is the Effect of Increasing the Parameters, brighterW or brighterL?

This parameter affects the brightness of the spectral band that is assigned to the green phosphor intensity in the IMAGE raster. This is the color that is NOT affected by redderW nor by redderL. Since the red phosphor intensity and the blue phosphor intensity are related, via the hue-shift model, to the green phosphor intensity, changing the green phosphor intensity affects all of the component colors in the same way.

G8. What is the Effect of Increasing the Parameters, brightenDarkW or brightenDarkL?

This parameter has an inverse relationship to the Power: factor of the Exponential contrast lookup table that is being formed by WATER.sml via the arrays called sBL_8, sGL_8, sRL_8, and/or sNA_8. As brightenDarkW or brightenDarkL are increased, the Power: factor decreases. This causes dark features to be brighter while bright features retain the same brightness.

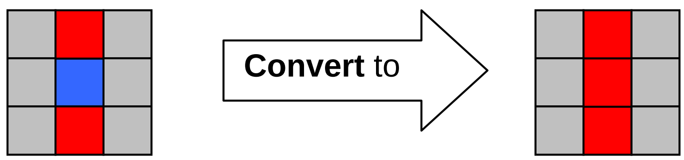
G9. How Does FILTER_WATERMASK.sml Improve a WATERMASK Raster?

Using an option in WATER.sml, you can produce a WATERMASK raster that is based strictly on the values of SRFIBL and SRFINA for each pixel.

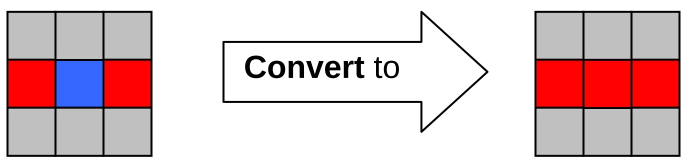
But, the results of this spectral algorithm are not perfect. Some actual land pixels have very dark SRFINA values and are, therefore, incorrectly classified as being water pixels. Examples of this kind of error are (1) shadows of trees and tall buildings, (2) dark paved roads, and (3) dark roofs. Some actual water pixels may be bright and red and are, therefore, incorrectly classified as being land pixels. However, this kind of spectral error is rare.

FILTER_WATERMASK.sml examines each water pixel in WATERMASK and exercises a set of spatial tests as follows:

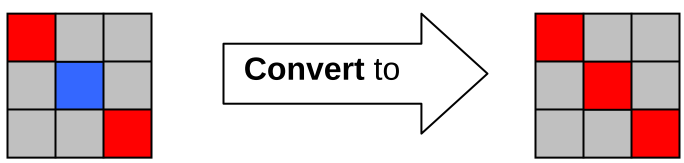
- If the two pixels on opposite sides of a water pixel are both land pixels, the water pixel is converted to a land pixel.
- This test is performed in four directions (blue for water pixel, red for land pixel, gray for pixels are not involved in the test):
  - **Line-Direction Test**:



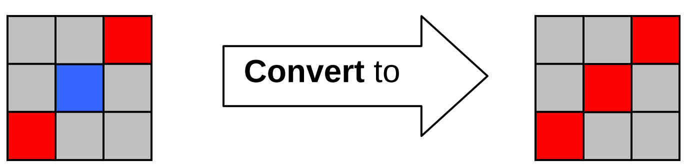
  - **Column-Direction Test**:



  - **Diagonal Test 1**:



  - **Diagonal Test 2**:



FILTER_WATERMASK.sml performs this set of localized spatial-pattern test over and over again on the modified WATERMASK raster until the number of water pixels converted to land pixels is equal to zero. Then, the script examines edge pixels to look for any remaining water pixels on any of the four edges that have a land pixel next to it in a direction away from the edge.

An example of how this process changes the initial WATERMASK raster to a modified WATERMASK raster is given in *Figure G9A* (the initial WATERMASK raster) and *Figure G9B* (the final modified WATERMASK raster). *Figure G9C* shows the water pixels that were converted to land pixels as green pixels. In all of these figures, blue pixels are water pixels, red pixels are land pixels, and green pixels are converted pixels.

No land pixels are converted to water pixels by FILTER_WATERMASK.sml.

You may run FILTER_WATERMASK.sml again on the modified WATERMASK raster to convert stray pixels that may still be wrongly classified as water pixels.

Figure G9A. Initial WATERMASK Raster: 4X Enlargement.

Figure G9B. Final, Modified WATERMASK Raster: 4X Enlargement.

Figure G9C. Final, Modified WATERMASK Raster with Changed Pixels in Green: 4X Enlargement.

Figure G9D. CIR Image (Based on SRFI Rasters): 4X Enlargement.

The FILTER_WATERMASK.sml algorithm does a good job in converting small and narrow would-be water pixels to correctly-classified land pixels. However, this process fails to convert some large in-land "water" objects to land objects. The two in-land "water" objects in *Figure G9B* and *Figure G9C* are examples of this failure. If you (as a human analyst) look at these two objects in the CIR image (*Figure G9D*), you can easily recognize them to be large (dark) asphalt parking lots in the city. In other parts of this QuickBird scene, however, there truly are such large water bodies that look similar (in terms of remotely-sensed properties).

So, you still need to edit the filtered WATERMASK raster in order to convert some (but not all) of the remaining inland apparent "water" object pixels to land pixels (if you deem this to be justified by your visual inspection of a reference raster such as the CIR image. This task is discussed in the next section of this tutorial.

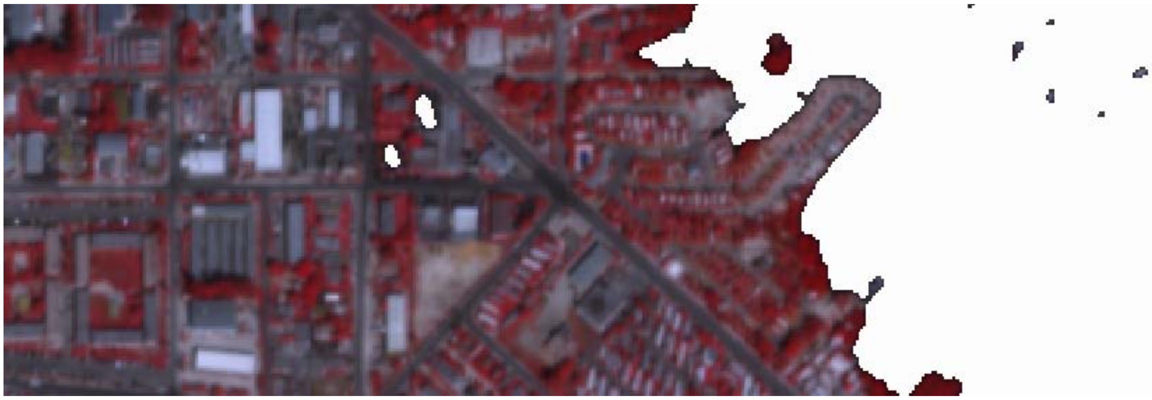
G10. How Can I Use TNTmips to Edit the Final WATERMASK Raster?

As we have seen above, the final modified WATERMASK raster still may have some imperfections in it. However, FILTER_WATERMASK.sml has correctly converted stray "water" pixels to the more correct class of land pixels. This greatly reduces the time that you have to spend manually editing the resulting WATERMASK raster using the TNTmips Spatial Data Editor.

Here are the steps that you should follow to manually edit the WATERMASK raster that emerged from the FILTER_WATERMASK.sml process:

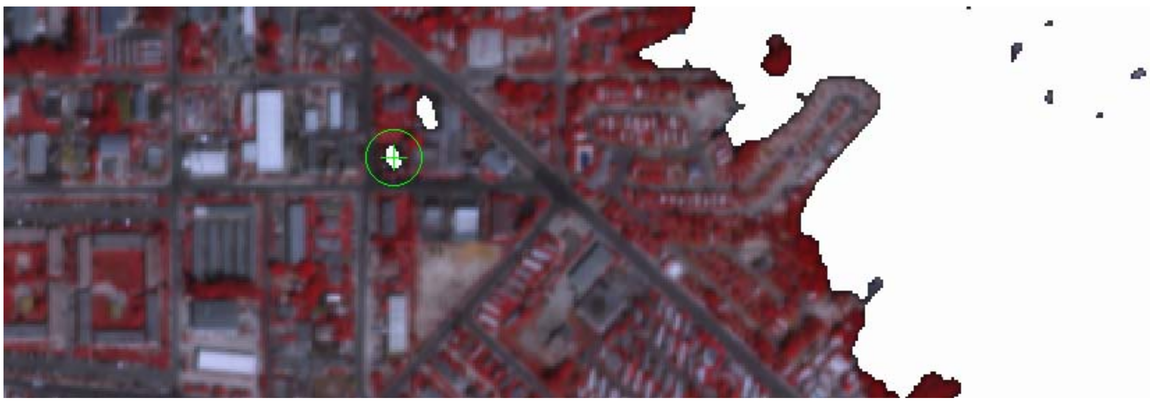
1. From the TNTmips main menu, select Edit then Spatial Data… . The Spatial Data Editor View 1 window and the Spatial Data Editor (control) box appear.
2. You need to select a Reference raster first. Click Reference, then Add Raster, then Add RGB Rasters… . Assign SRFINA to Red, SRFIRL to Green, and SRFIGL to Blue. Turn off the DataTips and allow the raster to be displayed. This RGB combo appears in the View 1 window (as an image) and appears in the Group control box as a layer.
3. Zoom into the upper left-hand corner at 2X. [Point to this corner and Press 2 on your keyboard.] Some of the land objects will be white. This can be confusing, so you need to temporarily change the contrast enhancements for the three rasters being displayed. To do this, click on the Tools icon in the Group control box. From the list, select Enhance Contrasts… . The Raster Contrast Enhancement control box appears.
4. For each color (Red, Green, and Blue), drag the upper dotted line on the left side of the control box to the top of the column. Do this for each primary color (change to a different color by clicking the associated Tab). Don't save this change … this is only done to make bright land objects turn darker (gray). Close the Raster Contrast Enhancement control box when you are finished. Redraw the View 1 view so that you can see the effects of temporarily changing the enhancement contrasts of the displayed "CIR" type RGB combo.
5. Now, you are ready to load the WATERMASK raster for editing. Be sure that you are willing to alter this raster. You may want to make a copy of it before you edit it (or save it as a different name when you are finished editing the raster). Click File, then Open… . Navigate to the WATERMASK raster that you want to edit. It will appear in the View 1 displayed "over" the reference CIR raster. You may see only the "water" pixels as a white color with the land pixels being transparent (or black). The display defaults to zeros being null values with null values being transparent (thus showing the CIR image). If the land pixels are black, use the Controls option or Edit Colors option to make the land pixels transparent. When you have done this, you should see something like the illustration in *Figure G10A* on the next page in the View 1 window.

Figure G10A. Appearance of the Spatial Data Editor View 1 Window after Loading Reference and WATERMASK Rasters.



Most of the white areas are truly water pixels. But, two of the inland "water" (white) areas are incorrectly classified (as being water). You can correct these errors by using the "flood fill" option.

6. Find the icon in the Raster Tools – Binary control box that is the Flood Fill (F) option. Select it. Be sure that the Cell… value related to this tool have a value of 0. To determine this, click the Cell… button.
7. When you click in the image, the flood-fill cursor shape appears (as shown below). You can drag this cursor so that the cross hairs are inside of a white area (area of "water" pixels) that you want to change to land pixels. See the illustration below.



8. When you Right Click (your mouse), the indicated white area will be "flooded" with the fill number (0). This number indicates that the pixels are land pixels (not water pixels anymore). The display will recognize this change and make the pixels transparent. So, now you see the CIR image in place of the previously white (water) pixels. This all happens as soon as you have clicked the Right (mouse) Button.

9. Move to the other white area and "flood fill" it with 0 values (indicating land pixels). Again, the area changes to show the Reference image.

When you have finished editing the WATERMASK raster, it will look like the illustration below:

10. Move to a different location and edit other incorrectly classified (white) "water" areas to convert them to land areas.
11. When you have finished, Click File then Save… or Save As… to save your edits. The first option will overwrite the WATERMASK raster. The second option will create a new WATERMASK raster.

Now that you have an excellent WATERMASK raster, you should rerun WATER.sml and use this EXISTING WATERMASK raster to control the color merging process.

G11. What Viewing Conditions Affect the Results?

If reflected sunlight from the water's surface is too bright, the results of using WATER.sml may be disappointing. Normally, the reflectance of water is small. Using Snell's Law of Reflectance, the power reflectance, r (a.k.a., reflectance) from a **smooth** water surface, at normal incidence, can be easily calculated, as follows:

$$\mathbf{r = 100\ (n_A - n_W)^2\ /\ (n_A + n_W)^2}$$

where

n_A = index of refraction of air (1.000)
n_W = index of refraction of water (1.33 in the visible region)
r = power reflectance (in percent)

With these values for n_A and n_W, **r = 2.01%**. This apparently low level of reflectance may not seem to be important compared to the reflectances of submerged features and/or of land features (3% - 40% reflectances).

However, the magnitude of reflectance is not the real issue.

Rather, the relative distribution of the reflected spectral radiance is the real issue. From a **smooth surface**, the reflected spectral radiance is focused into a small range of angles that are centered on the specular (mirror-like) upward-traveling direction. This specular direction is determined by a pair of angles, namely, the elevation angle and the azimuth angle of the downward-traveling sunlight.

For example, if the sun is in the southeast (azimuth angle = 135 degrees clockwise from north) with an elevation angle of 60 degrees, then the direction of reflected sunlight would be toward the northwest (azimuth angle = 315 degrees clockwise from the north) with an elevation angle of 60 degrees. If a camera were in an airplane (or in a spacecraft) looking downward toward smooth water, it would see a **small**, but **very bright image** of the reflected sun. The solar image would be very bright due to the high concentration of reflected sunlight into a small range of angles around the direction of travel of the reflected sunlight. The sun's reflected image would be much brighter than the brightness of the diffusely reflecting objects, such as, submerged water and/or land features.

However, if the water's surface were rough, then the reflected radiant energy would be spread out over a larger range of angles. The reflected image of the sun would appear larger than it does when the water's surface is smooth.

One parameter used to characterize the effects of surface roughness is the Forward Scattering Angle (FSA). FSA is the angle between a line of sight (from the observer to the target object) and the line of reflected sunlight from a smooth surface. For a given roughness, the spectral radiance of reflected sunlight decreases as FSA increases. And, for a given FSA, spectral radiance decreases as the roughness increases.

The roughness of a water surface is a complex function of many factors, including: wind speed, distance over which the wind has been acting on the water's surface (called the fetch), and the nature of waves that have moved into the area from distant sources. In general, surface roughness is not well known. A rule of thumb might be that the effects of surface roughness are of minimal importance (for viewing submerged features) when FSA is greater than 50 degrees. **So, to ensure that submerged features can be seen in a remotely-sensed image, it is best to select imaging geometries that result in a large FSA.** This would be the case, for example, when:

- Looking downward when the sun's elevation angle is small (e.g., winter in the Northern Hemisphere)
- Looking northwestward when the morning sun's elevation angle is large (e.g., summer in the Northern Hemisphere)

REFERENCES

Paris, J. F., 2005: Mapping submerged water features. *Earth Imaging Journal*, Vol. 2, No. 3, pp. 30-33. Available online.