1. Start ENVI
2. File, Open Image File
3. Navigate to product of choice
   1. .tif files are the primary image files (largest)
      1. “M1BS” indicates multispectral data
      2. “P1BS” indicates panchromatic data
   2. Different types of files:
      1. Uncalibrated “…u16ns3031.tif”
         1. No calibration or correction applied
         2. Loaded data will be listed as “Band 1,” “Band 2,” etc.
         3. Will take a very long time to load each band
         4. Data will be in integer format (no decimals)
      2. Calibrated to radiance “…\_rad.tif” (proceed to Step A)
         1. Calibrated to top-of-atmosphere radiance
            1. Removes sensor-specific properties and puts the data into a standard radiometric format that can be further calibrated
         2. Each displayed band will be named a “Band Math” equation, and will likely be assigned a specific central wavelength (in micrometers)
         3. Will load much more quickly
         4. Data will be in decimal format
      3. Masked radiance data (will have “mask” in the name)
         1. Same as calibrated radiance data
         2. No need to worry about creating spectral masks for the purposes of this work
      4. Atmospherically corrected data
         1. Will contain either “atmcorr” or “scatsub” in the file name
         2. The terms “rad” and “refl” may appear in the file name:
            1. If only “rad” appears, proceed to Step B only
            2. If “refl” appears, proceed to Step B and continue to Step C
      5. Parameterized data (will have “param” in the file name)
         1. Proceed to Step D

**WorldView-2**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Band** | **Band Name** | **Central Wavelength (µm)** | **Effective Bandwidth (µm)** | **Solar Exoatmospheric Spectral Irradiance (ESUNλ)** |
| Band 1 | Coastal | 0.427 | 0.0473 | 1758.2229 |
| Band 2 | Blue | 0.478 | 0.0543 | 1974.2416 |
| Band 3 | Green | 0.546 | 0.0630 | 1856.4104 |
| Band 4 | Yellow | 0.608 | 0.0374 | 1738.4791 |
| Band 5 | Red | 0.659 | 0.0574 | 1559.4555 |
| Band 6 | Red Edge | 0.724 | 0.0393 | 1342.0695 |
| Band 7 | Near-IR 1 | 0.931 | 0.0989 | 1069.7302 |
| Band 8 | Near-IR 2 | 0.908 | 0.0996 | 861.2866 |

**WorldView-3**

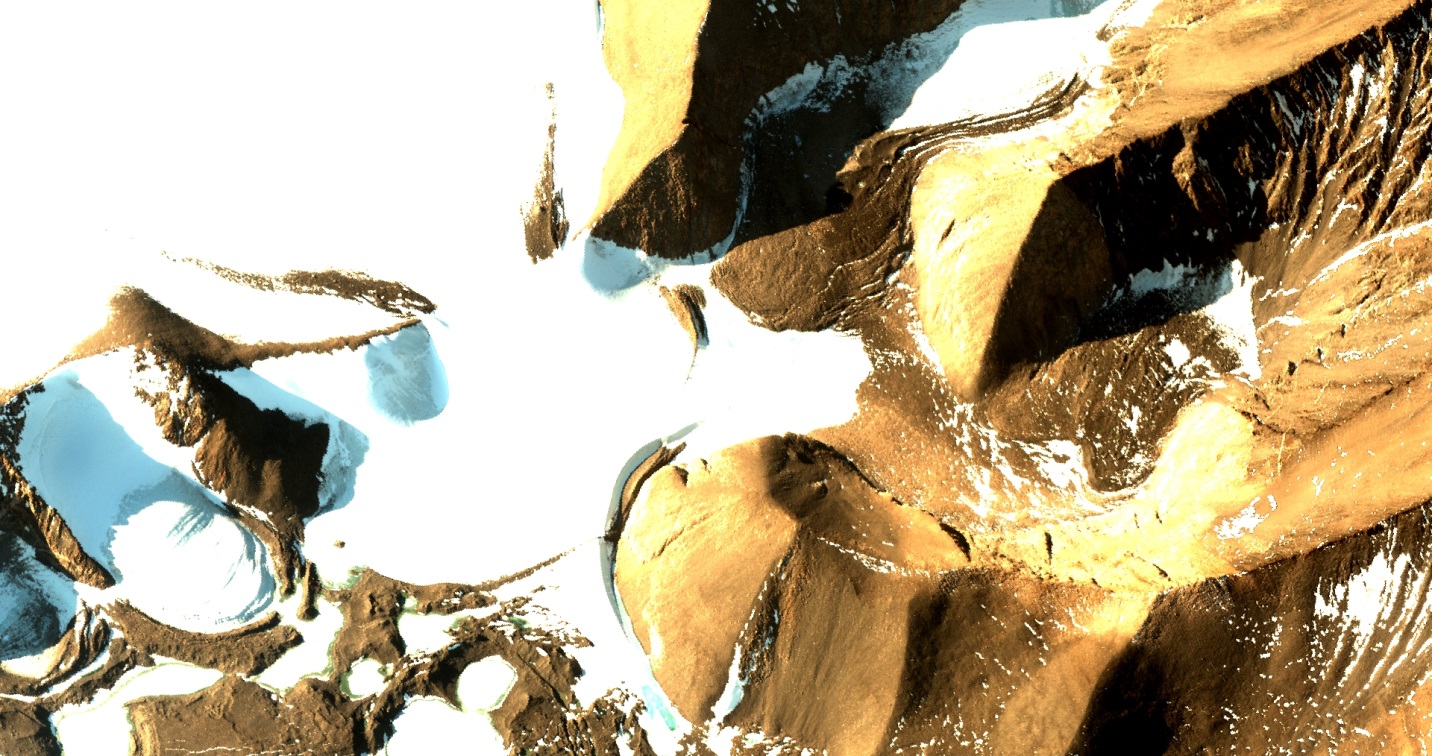
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Band** | **Band Name** | **Central Wavelength (µm)** | **Effective Bandwidth (µm)** | **Solar Exoatmospheric Spectral Irradiance (ESUNλ)** |
| Band 1 | Coastal | 0.427 | 0.0405 | 1803.9109 |
| Band 2 | Blue | 0.482 | 0.0540 | 1982.4485 |
| Band 3 | Green | 0.547 | 0.0618 | 1857.1232 |
| Band 4 | Yellow | 0.604 | 0.0381 | 1746.5947 |
| Band 5 | Red | 0.660 | 0.0585 | 1556.9730 |
| Band 6 | Red Edge | 0.723 | 0.0387 | 1340.6822 |
| Band 7 | Near-IR 1 | 0.824 | 0.1004 | 1072.5267 |
| Band 8 | Near-IR 2 | 0.913 | 0.0889 | 871.1058 |

Step A: Calibrating from raw data to radiance

* Outside of ENVI, open and view the .xml file that accompanies the image that you are trying to calibrate
* Record the “ABSCALFACTOR” value that is listed under each band. Be sure to keep track of the scientific notation
  + E.g., 9.295654e-03 is equal to 0.009295654
* In ENVI, go to File, Open Image File
* Then, in ENVI, go to Basic Tools, Band Math
  + Under “Enter an expression:” use the information provided on this sheet and the information gathered from the .xml file to produce a separate equation for each spectral band in the image
    - ([Band 1 ABSCALFACTOR] \* b1) / [Band 1 Effective Bandwidth]
      * Will actually look like this: **(0.009295654\*b1)/0.0473**
      * The second expression will look like this: **(0.012608250\*b2)/0.0543**
  + Apply each expression to its corresponding spectral band
    - Under “Output Result to,” select “Memory”
      * You may get an “ENVI Output to Memory Warning” message, which indicates that your request requires a lot of memory. Indicate “Memory” again to override this warning
* You will have now produced eight new image files, each with a single band
* To combine these individual files into a single, eight-band image:
  + Go to Basic Tools, Layer Stacking
  + Click on “Import File…” and select all of the temporary image files produced in the previous step
  + Click on “Reorder Files…” and make sure that the bands are in proper order
    - This can get tricky, as “Memory1” and “Memory2” might not correspond to the band values that you were processing
    - If unclear, go back to the “Available Bands List” window and look at the equations applied to each new image file. Write down the band number that’s associated with each Memory file
    - Once known, under “Reorder Files,” drag the bands so that they appear in the proper descending order, with Band 1 at the top and Band 8 at the bottom
  + Leave all other properties the same – they should have been inherited from your original images
  + Under “Output Result to,” select “File” and under “Enter Output Filename,” click “Choose”
    - Navigate to the original file name that you have been processing
    - Select that filename (which should end in “.tif”) and add “\_rad” before the file extension
      * The new filename should now look like “…\_rad.tif”
* Before closing the file in ENVI, right-click on the file name in the “Available Bands List” and select “Edit Header”
  + Under the “Edit Attributes” pull-down menu, select “Wavelengths”
  + Under the “Wavelength/FWHM Units” menu, select “Micrometers”
  + Click the “Import ASCII…” button and navigate to the file entitled “wv2\_bands.txt” in the main data folder
  + In the new box that appears, enter “1” in the “Wavelength Column” category, and enter “2” in the “FWHM Column” (Full-Width Half-Maximum) category
  + Select OK and proceed through the steps to assign these new wavelength values
    - If successful, this will close the open image window
    - No need to resave the data, it automatically updates it

Step B: Atmospherically correcting radiance data

* Atmospheric correction requires several assumptions
  + (1) The atmosphere throughout the scene is homogeneous and does not change
    - If there are clouds in the image, this is an obvious imperfection in this assumption, but it is the best we are able to do at this point
  + (2) The surfaces that we will use to derive the atmospheric correction are compositionally and spectrally homogeneous and unvarying
* Explore the radiance file image in ENVI, navigating throughout the scene and identifying the different geologic regions
* The Dark Object Subtraction & Regression (DOS-R) technique uses dark geologic surfaces (not ice or snow) under differing illumination conditions to back-out atmospheric scattering properties
* Find an area of ice- and snow-free surface that exhibits both shadowed and non-shadowed surfaces
  + Ideally, you would like to find bright surfaces, dark surfaces, and a smooth transition between the two
    - Typically best found on gradually sloping hillsides
      * The image below has some candidate locations circled in red:



* + - Remember that you want to do your best to ensure that the composition, color, or other spectral properties of the surface in that specific location is largely homogeneous, i.e. there are no obvious changes in color from brown to tan associated with a new rock unit
* When you have identified a candidate location, go to the “Zoom” window that is automatically displayed with each image, right-click in the window, and select “Z Profile (Spectrum)”
  + This will pop up a spectral profile, taken from the pixel highlighted in the Zoom window
* Click in the Zoom window to navigate to some of the brightest pixels in your region of interest
* Then, right-click on the spectral profile window and select “Collect Spectra”
  + This step will begin to collect and save spectra every time you move the cursor in the Zoom window
* Begin to collect spectra from the bright regions, the dark regions, and the intermediate regions, using either your mouse or the keyboard arrows to navigate
  + You want to collect at least 100 spectra from this location
    - No more than 200 pixels are necessary
  + The spectra will eventually be used to determine a *linear regression* for your data, which means there is a bit of an art to the data collection process
    - If you collect too many dark or bright pixels, then the regression line must be drawn through a data *blob*
    - The art is to select the majority of the pixels from the intermediate bright/dark regions, with a few “endmembers” of bright and dark pixels
      * Maybe a ratio of 20% dark pixels, 20% bright pixels, and 60% intermediate pixels
* Once you’ve collected all of the pixels of interest:
  + In the spectral profile window, select File, Save Plot As, ASCII
  + Click the “Select All Items” button
  + Keep the X and Y Precision values at “6” – this is the number of decimal places to save the data to
  + Click “Choose” under “Enter Output Filename [.txt]”
    - Click on the filename of the image of interest
      * The one ending in “\_rad.tif”
    - Alter the name to end as “\_rad\_atmcorr1.txt”
  + Save the text file
* Open a blank Microsoft Excel document
  + Go to File, Open
  + In the bottom-right corner of the navigation dialog, be sure to change the visible file extensions from “All Excel Files” to “All Files”
  + Open the file that you just saved, this will open the “Text Import Wizard” dialog
    - Ensure that the “Delimited” radio button is selected, click Next
    - Check the “Space” button, then click Finish
* Scroll to the bottom of the opened Excel document
  + Your data are now located in the final eight rows
  + The first column is blank, the second column contains your spectral wavelengths, and the third column starts the actual data
    - Each column represents a single spectrum
* Outside of Excel, navigate to the file entitled “atmcorr\_worksheet.xlsx” and open it
* Go back to the first Excel file with all of your data
  + Highlight all of the data files, starting with the third column
  + Copy these data (using CTRL-C)
* Go back to the “atmcorr\_worksheet.xlsx” file, click on the *PASTE HERE* box located in Cell B2, and click CTRL-V to paste your data there
* Determine whether your data produce a good atmospheric scattering spectrum
  + If the “B1TEST,” “B2TEST,” etc. values turn green and say “PASS,” then the data quality are good and a good atmospheric spectrum was produced.
* **Repeat the atmospheric correction process at least another two times, starting with identifying a suitable location in the image**
  + Ideally, you’ll want to generate these tests for different parts of the image (the top-left quadrant, the bottom-right quadrant, etc.)
  + Repeat all of these steps, and paste your data in the same “atmcorr\_worksheet.xlsx” file in the space below
* What happens if you receive any “FAIL” values in the “atmcorr\_worksheet.xlsx” file?
  + If the entire row shows “FAIL,” then you will likely need to throw away that atmospheric correction
  + If a few cells say “PASS” and a few cells say “FAIL,” consult the grey values immediately below those cells
    - If the failed values are < 5.0, then you may be able to use these data if you are having trouble finding suitable atmospheric correction candidate locations
    - If the failed values are > 5.0, then you will likely need to throw away that atmospheric correction
* Ideally, you want to have at least three fully passing atmospheric corrections
  + If you cannot find three suitable locations, and one of your corrections fails with values < 5.0, then you may still use that correction
  + Otherwise, if you have one good passing atmospheric correction (grey values all < 1.5 or so), then you may use a single atmospheric scattering location to perform the atmospheric correction
* Once you are satisfied with your progress and are ready to implement the atmospheric correction:
  + In Excel, scroll down to Row 61-68
  + In Cell B62, the equation should state “=AVERAGE(C62:G62)”
    - Change the equation to only include the cells that have values within them
      * E.g., if you only had three atmospheric spectra derived, then only rows C through E will be filled, so change the equation to state “=AVERAGE(C62:E62)”
    - After changing the B62 cell, implement the same change to all of the blue cells
  + Go to File, Save As, and save the worksheet as a new file
    - Navigate to the image that you are working on, and change the file name to end with “\_rad\_atmcorr\_worksheet.xlsx”
* Go back to ENVI and the image’s Zoom window
  + Go to the Spectral Profile window and deselect “Collect Spectra”
    - Click anywhere in the image to display only one single spectrum
  + In the Spectral Profile window, go to Options, New Window: With Plots
    - This will display a new profile window with the spectrum that you had previously selected
    - In that window, select Edit, Data Values
      * Click on the first data value and change that value to the B1 atmcorr value derived in the blue cells of the Excel worksheet
      * Repeat this step for all of the values, then click OK
    - In that window, select Edit, Data Parameters
      * In the “Name” category, change the name to “atmcorr”, select Apply and close the window
* In the main ENVI menu, select Basic Tools, Spectral Math
  + Under “Enter and expression:,” type “**s1-s2**” (without quotes) and click OK
    - Highlight S1 and click the “Map Variable to Input File” button
      * Then, select the image file ending in “…\_rad.tif” and click OK
    - Highlight S2 and select the “atmcorr” spectrum that you just created
  + Click the Choose button next to the “Enter Output Filename” option
    - Save the file as the same image file with the new extension “…\_rad\_atmcorr.tif”

Step C: Converting radiance data to reflectance data

* To be completed following the atmospheric correction stage, which converts top-of-atmosphere radiance to surface radiance
  + Start with the image file that ends with “…\_rad\_atmcorr.tif”
* Outside of ENVI, open and view the .xml file that accompanies the image that you are trying to calibrate
  + Find the value associated with “MEANSUNEL” (towards the bottom)
    - Remember to keep track of the scientific notation!
* Using the table provided below, record the Earth-Sun distance (d) in Astronomical Units corresponding to the day the image was collected
  + Hint: this information is contained in the image name (e.g., if “10DEC16” is included in the image name, it indicates Dec. 16th, 2010)
  + If a leap day is required, use the value associated with March 1st

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **DOY** | **d (AU)** | **DOY** | **d (AU)** | **DOY** | **d (AU)** | **DOY** | **d (AU)** | **DOY** | **d (AU)** | **DOY** | **d (AU)** |
| **1-Jan** | 0.98331 | **2-Mar** | 0.99108 | **1-May** | 1.00756 | **30-Jun** | 1.01665 | **29-Aug** | 1.00992 | **28-Oct** | 0.99359 |
| **2-Jan** | 0.98330 | **3-Mar** | 0.99133 | **2-May** | 1.00781 | **1-Jul** | 1.01667 | **30-Aug** | 1.00969 | **29-Oct** | 0.99332 |
| **3-Jan** | 0.98330 | **4-Mar** | 0.99158 | **3-May** | 1.00806 | **2-Jul** | 1.01668 | **31-Aug** | 1.00946 | **30-Oct** | 0.99306 |
| **4-Jan** | 0.98330 | **5-Mar** | 0.99183 | **4-May** | 1.00831 | **3-Jul** | 1.01670 | **1-Sep** | 1.00922 | **31-Oct** | 0.99279 |
| **5-Jan** | 0.98330 | **6-Mar** | 0.99208 | **5-May** | 1.00856 | **4-Jul** | 1.01670 | **2-Sep** | 1.00898 | **1-Nov** | 0.99253 |
| **6-Jan** | 0.98332 | **7-Mar** | 0.99234 | **6-May** | 1.00880 | **5-Jul** | 1.01670 | **3-Sep** | 1.00874 | **2-Nov** | 0.99228 |
| **7-Jan** | 0.98333 | **8-Mar** | 0.99260 | **7-May** | 1.00904 | **6-Jul** | 1.01670 | **4-Sep** | 1.00850 | **3-Nov** | 0.99202 |
| **8-Jan** | 0.98335 | **9-Mar** | 0.99286 | **8-May** | 1.00928 | **7-Jul** | 1.01669 | **5-Sep** | 1.00825 | **4-Nov** | 0.99177 |
| **9-Jan** | 0.98338 | **10-Mar** | 0.99312 | **9-May** | 1.00952 | **8-Jul** | 1.01668 | **6-Sep** | 1.00800 | **5-Nov** | 0.99152 |
| **10-Jan** | 0.98341 | **11-Mar** | 0.99339 | **10-May** | 1.00975 | **9-Jul** | 1.01666 | **7-Sep** | 1.00775 | **6-Nov** | 0.99127 |
| **11-Jan** | 0.98345 | **12-Mar** | 0.99365 | **11-May** | 1.00998 | **10-Jul** | 1.01664 | **8-Sep** | 1.00750 | **7-Nov** | 0.99102 |
| **12-Jan** | 0.98349 | **13-Mar** | 0.99392 | **12-May** | 1.01020 | **11-Jul** | 1.01661 | **9-Sep** | 1.00724 | **8-Nov** | 0.99078 |
| **13-Jan** | 0.98354 | **14-Mar** | 0.99419 | **13-May** | 1.01043 | **12-Jul** | 1.01658 | **10-Sep** | 1.00698 | **9-Nov** | 0.99054 |
| **14-Jan** | 0.98359 | **15-Mar** | 0.99446 | **14-May** | 1.01065 | **13-Jul** | 1.01655 | **11-Sep** | 1.00672 | **10-Nov** | 0.99030 |
| **15-Jan** | 0.98365 | **16-Mar** | 0.99474 | **15-May** | 1.01087 | **14-Jul** | 1.01650 | **12-Sep** | 1.00646 | **11-Nov** | 0.99007 |
| **16-Jan** | 0.98371 | **17-Mar** | 0.99501 | **16-May** | 1.01108 | **15-Jul** | 1.01646 | **13-Sep** | 1.00620 | **12-Nov** | 0.98983 |
| **17-Jan** | 0.98378 | **18-Mar** | 0.99529 | **17-May** | 1.01129 | **16-Jul** | 1.01641 | **14-Sep** | 1.00593 | **13-Nov** | 0.98961 |
| **18-Jan** | 0.98385 | **19-Mar** | 0.99556 | **18-May** | 1.01150 | **17-Jul** | 1.01635 | **15-Sep** | 1.00566 | **14-Nov** | 0.98938 |
| **19-Jan** | 0.98393 | **20-Mar** | 0.99584 | **19-May** | 1.01170 | **18-Jul** | 1.01629 | **16-Sep** | 1.00539 | **15-Nov** | 0.98916 |
| **20-Jan** | 0.98401 | **21-Mar** | 0.99612 | **20-May** | 1.01191 | **19-Jul** | 1.01623 | **17-Sep** | 1.00512 | **16-Nov** | 0.98894 |
| **21-Jan** | 0.98410 | **22-Mar** | 0.99640 | **21-May** | 1.01210 | **20-Jul** | 1.01616 | **18-Sep** | 1.00485 | **17-Nov** | 0.98872 |
| **22-Jan** | 0.98419 | **23-Mar** | 0.99669 | **22-May** | 1.01230 | **21-Jul** | 1.01609 | **19-Sep** | 1.00457 | **18-Nov** | 0.98851 |
| **23-Jan** | 0.98428 | **24-Mar** | 0.99697 | **23-May** | 1.01249 | **22-Jul** | 1.01601 | **20-Sep** | 1.00430 | **19-Nov** | 0.98830 |
| **24-Jan** | 0.98439 | **25-Mar** | 0.99725 | **24-May** | 1.01267 | **23-Jul** | 1.01592 | **21-Sep** | 1.00402 | **20-Nov** | 0.98809 |
| **25-Jan** | 0.98449 | **26-Mar** | 0.99754 | **25-May** | 1.01286 | **24-Jul** | 1.01584 | **22-Sep** | 1.00374 | **21-Nov** | 0.98789 |
| **26-Jan** | 0.98460 | **27-Mar** | 0.99782 | **26-May** | 1.01304 | **25-Jul** | 1.01575 | **23-Sep** | 1.00346 | **22-Nov** | 0.98769 |
| **27-Jan** | 0.98472 | **28-Mar** | 0.99811 | **27-May** | 1.01321 | **26-Jul** | 1.01565 | **24-Sep** | 1.00318 | **23-Nov** | 0.98750 |
| **28-Jan** | 0.98484 | **29-Mar** | 0.99840 | **28-May** | 1.01338 | **27-Jul** | 1.01555 | **25-Sep** | 1.00290 | **24-Nov** | 0.98731 |
| **29-Jan** | 0.98496 | **30-Mar** | 0.99868 | **29-May** | 1.01355 | **28-Jul** | 1.01544 | **26-Sep** | 1.00262 | **25-Nov** | 0.98712 |
| **30-Jan** | 0.98509 | **31-Mar** | 0.99897 | **30-May** | 1.01371 | **29-Jul** | 1.01533 | **27-Sep** | 1.00234 | **26-Nov** | 0.98694 |
| **31-Jan** | 0.98523 | **1-Apr** | 0.99926 | **31-May** | 1.01387 | **30-Jul** | 1.01522 | **28-Sep** | 1.00205 | **27-Nov** | 0.98676 |
| **1-Feb** | 0.98536 | **2-Apr** | 0.99954 | **1-Jun** | 1.01403 | **31-Jul** | 1.01510 | **29-Sep** | 1.00177 | **28-Nov** | 0.98658 |
| **2-Feb** | 0.98551 | **3-Apr** | 0.99983 | **2-Jun** | 1.01418 | **1-Aug** | 1.01497 | **30-Sep** | 1.00148 | **29-Nov** | 0.98641 |
| **3-Feb** | 0.98565 | **4-Apr** | 1.00012 | **3-Jun** | 1.01433 | **2-Aug** | 1.01485 | **1-Oct** | 1.00119 | **30-Nov** | 0.98624 |
| **4-Feb** | 0.98580 | **5-Apr** | 1.00041 | **4-Jun** | 1.01447 | **3-Aug** | 1.01471 | **2-Oct** | 1.00091 | **1-Dec** | 0.98608 |
| **5-Feb** | 0.98596 | **6-Apr** | 1.00069 | **5-Jun** | 1.01461 | **4-Aug** | 1.01458 | **3-Oct** | 1.00062 | **2-Dec** | 0.98592 |
| **6-Feb** | 0.98612 | **7-Apr** | 1.00098 | **6-Jun** | 1.01475 | **5-Aug** | 1.01444 | **4-Oct** | 1.00033 | **3-Dec** | 0.98577 |
| **7-Feb** | 0.98628 | **8-Apr** | 1.00127 | **7-Jun** | 1.01488 | **6-Aug** | 1.01429 | **5-Oct** | 1.00005 | **4-Dec** | 0.98562 |
| **8-Feb** | 0.98645 | **9-Apr** | 1.00155 | **8-Jun** | 1.01500 | **7-Aug** | 1.01414 | **6-Oct** | 0.99976 | **5-Dec** | 0.98547 |
| **9-Feb** | 0.98662 | **10-Apr** | 1.00184 | **9-Jun** | 1.01513 | **8-Aug** | 1.01399 | **7-Oct** | 0.99947 | **6-Dec** | 0.98533 |
| **10-Feb** | 0.98680 | **11-Apr** | 1.00212 | **10-Jun** | 1.01524 | **9-Aug** | 1.01383 | **8-Oct** | 0.99918 | **7-Dec** | 0.98519 |
| **11-Feb** | 0.98698 | **12-Apr** | 1.00240 | **11-Jun** | 1.01536 | **10-Aug** | 1.01367 | **9-Oct** | 0.99890 | **8-Dec** | 0.98506 |
| **12-Feb** | 0.98717 | **13-Apr** | 1.00269 | **12-Jun** | 1.01547 | **11-Aug** | 1.01351 | **10-Oct** | 0.99861 | **9-Dec** | 0.98493 |
| **13-Feb** | 0.98735 | **14-Apr** | 1.00297 | **13-Jun** | 1.01557 | **12-Aug** | 1.01334 | **11-Oct** | 0.99832 | **10-Dec** | 0.98481 |
| **14-Feb** | 0.98755 | **15-Apr** | 1.00325 | **14-Jun** | 1.01567 | **13-Aug** | 1.01317 | **12-Oct** | 0.99804 | **11-Dec** | 0.98469 |
| **15-Feb** | 0.98774 | **16-Apr** | 1.00353 | **15-Jun** | 1.01577 | **14-Aug** | 1.01299 | **13-Oct** | 0.99775 | **12-Dec** | 0.98457 |
| **16-Feb** | 0.98794 | **17-Apr** | 1.00381 | **16-Jun** | 1.01586 | **15-Aug** | 1.01281 | **14-Oct** | 0.99747 | **13-Dec** | 0.98446 |
| **17-Feb** | 0.98814 | **18-Apr** | 1.00409 | **17-Jun** | 1.01595 | **16-Aug** | 1.01263 | **15-Oct** | 0.99718 | **14-Dec** | 0.98436 |
| **18-Feb** | 0.98835 | **19-Apr** | 1.00437 | **18-Jun** | 1.01603 | **17-Aug** | 1.01244 | **16-Oct** | 0.99690 | **15-Dec** | 0.98426 |
| **19-Feb** | 0.98856 | **20-Apr** | 1.00464 | **19-Jun** | 1.01610 | **18-Aug** | 1.01225 | **17-Oct** | 0.99662 | **16-Dec** | 0.98416 |
| **20-Feb** | 0.98877 | **21-Apr** | 1.00492 | **20-Jun** | 1.01618 | **19-Aug** | 1.01205 | **18-Oct** | 0.99634 | **17-Dec** | 0.98407 |
| **21-Feb** | 0.98899 | **22-Apr** | 1.00519 | **21-Jun** | 1.01625 | **20-Aug** | 1.01186 | **19-Oct** | 0.99605 | **18-Dec** | 0.98399 |
| **22-Feb** | 0.98921 | **23-Apr** | 1.00546 | **22-Jun** | 1.01631 | **21-Aug** | 1.01165 | **20-Oct** | 0.99577 | **19-Dec** | 0.98391 |
| **23-Feb** | 0.98944 | **24-Apr** | 1.00573 | **23-Jun** | 1.01637 | **22-Aug** | 1.01145 | **21-Oct** | 0.99550 | **20-Dec** | 0.98383 |
| **24-Feb** | 0.98966 | **25-Apr** | 1.00600 | **24-Jun** | 1.01642 | **23-Aug** | 1.01124 | **22-Oct** | 0.99522 | **21-Dec** | 0.98376 |
| **25-Feb** | 0.98989 | **26-Apr** | 1.00626 | **25-Jun** | 1.01647 | **24-Aug** | 1.01103 | **23-Oct** | 0.99494 | **22-Dec** | 0.98370 |
| **26-Feb** | 0.99012 | **27-Apr** | 1.00653 | **26-Jun** | 1.01652 | **25-Aug** | 1.01081 | **24-Oct** | 0.99467 | **23-Dec** | 0.98363 |
| **27-Feb** | 0.99036 | **28-Apr** | 1.00679 | **27-Jun** | 1.01656 | **26-Aug** | 1.01060 | **25-Oct** | 0.99440 | **24-Dec** | 0.98358 |
| **28-Feb** | 0.99060 | **29-Apr** | 1.00705 | **28-Jun** | 1.01659 | **27-Aug** | 1.01037 | **26-Oct** | 0.99412 | **25-Dec** | 0.98353 |
| **1-Mar** | 0.99084 | **30-Apr** | 1.00731 | **29-Jun** | 1.01662 | **28-Aug** | 1.01015 | **27-Oct** | 0.99385 | **26-Dec** | 0.98348 |
|  |  |  |  |  |  |  |  |  |  | **27-Dec** | 0.98344 |
|  |  |  |  |  |  |  |  |  |  | **28-Dec** | 0.98340 |
|  |  |  |  |  |  |  |  |  |  | **29-Dec** | 0.98337 |
|  |  |  |  |  |  |  |  |  |  | **30-Dec** | 0.98335 |

* In the main ENVI toolbar, go to Basic Tools, Band Math
  + The following equation is required to be used for each spectral band (similar to the original calculation of radiance):
  + Before proceeding any further, use a calculator to calculate cos(θ), where θ is the MEANSUNEL value derived from the .xml file
  + Use the table on the first page to determine the ESUNλ value for each band
  + The above equation can be translated to the following ENVI format:
    - **(3.14159\*b1\**0.99060\*0.99060*)/(1758.2229\**0.85173*)**
      * Italic values require changing depending on d and θ
  + Apply each expression to its corresponding spectral band
    - Under “Output Result to,” select “Memory”
      * You may get an “ENVI Output to Memory Warning” message, which indicates that your request requires a lot of memory. Indicate “Memory” again to override this warning
* You will have now produced eight new image files, each with a single band
* To combine these individual files into a single, eight-band image:
  + Go to Basic Tools, Layer Stacking
  + Click on “Import File…” and select all of the temporary image files produced in the previous step
  + Click on “Reorder Files…” and make sure that the bands are in proper order
    - This can get tricky, as “Memory1” and “Memory2” might not correspond to the band values that you were processing
    - If unclear, go back to the “Available Bands List” window and look at the equations applied to each new image file. Write down the band number that’s associated with each Memory file
    - Once known, under “Reorder Files,” drag the bands so that they appear in the proper descending order, with Band 1 at the top and Band 8 at the bottom
  + Leave all other properties the same – they should have been inherited from your original images
  + Under “Output Result to,” select “File” and under “Enter Output Filename,” click “Choose”
    - Navigate to the original file name that you have been processing
    - Select that filename (which should end in “.tif”) and add “\_refl” before the file extension
      * The new filename should now look like “…\_rad\_atmcorr\_refl.tif”
* Before closing the file in ENVI, right-click on the file name in the “Available Bands List” and select “Edit Header”
  + Under the “Edit Attributes” pull-down menu, select “Wavelengths”
  + Under the “Wavelength/FWHM Units” menu, select “Micrometers”
  + Click the “Import ASCII…” button and navigate to the file entitled “wv2\_bands.txt” in the main data folder
  + In the new box that appears, enter “1” in the “Wavelength Column” category, and enter “2” in the “FWHM Column” (Full-Width Half-Maximum) category
  + Select OK and proceed through the steps to assign these new wavelength values
    - If successful, this will close the open image window
    - No need to resave the data, it automatically updates it