**Processing and Calibrating WorldView-2 Data to Surface Reflectance**

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1. Start ENVI
2. File, Open Image File
3. Navigate to image of choice
   1. Each folder corresponds to an image “strip,” which contains several image scenes
   2. Open each individual scene to see whether that subset intersects with a region of interest
   3. Proceed to Step A below

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **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 | 0.831 | 0.0989 | 1069.7302 |
| Band 8 | Near-IR 2 | 0.908 | 0.0996 | 861.2866 |

Step A: Calibrating from raw data to radiance

* Outside of ENVI, open and view the .xml file that accompanies the image strip 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 will use the dark object subtraction and regression (DOS-R) method:
  + Using a combination of spectral band combinations and parameters, identify locations with significant topography that are spectrally homogeneous and are not varying greatly over small spatial scales
  + Once identified, search for small regions where solar illumination and shadows (influenced by topography) vary greatly
  + Collect between 100 and 200 spectra from a spectrally homogeneous region under different illumination conditions, including some fully in shadow and some as directly illuminated as possible
  + Save the spectra as an ascii (text) file
  + Incorporate these spectra into the Atmospheric Correction Worksheet (Excel file)
    - Load the txt file into Excel
    - Exclude all rows that have superfluous header information, so that the first row is simply the name of the spectrum, and each subsequent row corresponds to a given wavelength
    - Copy everything (excluding the originally removed superfluous header information), including the column names, wavelengths, and all data
    - Paste the data where the Excel sheet says “Paste Here”
      * Behind the scenes, Excel is plotting the radiance value of each band versus the radiance value of Band 8 (minimally influenced by atmospheric scattering)
      * Excel then plots a regression line through the data and records the Y-intercept, which corresponds to the predicted value of each band when Band 8 is equal to zero (i.e., fully in shadow and not influenced by any solar illumination)
      * The “PASS” and “FAIL” indicators that come up are based on a quick and dirty mathematical estimate of what constitutes a “good” and “bad” regression fit
        + To ensure that the regression looks appropriate and that the plots are generally linear, visualize the plot itself and determine whether the regression accurately represents the data
  + Repeat the above steps in a total of five locations spread throughout the scene
  + Once all five locations are repeated, there should be average spectral values that are displayed for bands 1 through 7 at the bottom of the worksheet
    - These values indicate the average atmospheric scattering contributions and must be removed from the scene
    - Remember that the value for Band 8 in all of these scenarios is, by definition, zero
  + Display a spectrum from anywhere in the scene
    - Go to “Edit” and select “Data Values”
    - Change the values for each band to the values displayed in the Excel file
      * Don’t forget to change the value of Band 8 to zero!
  + Subtract the atmospheric spectrum from the radiance image
    - Go to “Basic Tools” and select “Band Math”
    - Enter the expression “**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 sin(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

Step D: Calculating Spectral Parameters (Including NDVI)

* Once the data have been successfully calibrated to surface reflectance, it is relatively simple to generate derived spectral products (like NDVI)
* Navigate to Basic Tools, Band Math in the main ENVI window
* Type the equation for whichever spectral parameter you would like to calculate
  + For calculating NDVI using WorldView-2 data, the equation will be:
    - (B7-B5)/(B7+B5)
* Assign the appropriate bands to the equation
* Under “Output Results to,” select File
  + Choose an appropriate filename and location to save the data
  + Ensure that the filename entered has a “.tif” extension to it, indicating that the created file should be in a GeoTIFF format
* Save the result
  + If the file was generated from a georeferenced dataset, and if the saved file has the “.tif” extension on the end, then the resultant file should be fully compatible with ArcGIS