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Procedure for processing LRO WAC monochromatic images with ISIS 3 for photogeologic purposes
v. 1.1

0. The learning curve with ISIS can be pretty steep, particularly if you're not a GISsing / image processing / Linuxing sort of a person (I'm not), so these short instructions are meant to make it a bit easier for a beginner to produce LRO WAC images and mosaics that can be used for photogeologic analysis and various other purposes. These instructions assume that you are familiar with ISIS, and that you have succesfully installed it on your computer (that can be easier said than done). My "*A beginner's guide to stereo-derived DEM production and analysis using ISIS, ASP, and ArcMap*" (available online at
http://www.lpi.usra.edu/lunar/tools/dems/Ohman_2013_ISIS-ASP-ArcMap_workflow.pdf
or at
http://www.researchgate.net/publication/276294107_A_beginners_guide_to_stereo-derived_DEM_production_and_analysis_using_ISIS_ASP_and_ArcMap)
is helpful in getting the hang of the very basics of ISIS, or at least I think it is.

What I'm presenting here may not be the best way to do these things (level 0 – level 4 processing), but it works, which for me is the most crucial thing. Note that the *photometric calibration* (step 4) presented here only produces "pretty" images than can be mosaicked together, and *it is not the scientifically correct way and should not be used for any sort of photometric or spectroscopic work!* It does, however, give perfectly valid results for photogeologic work. And remember that these instructions only apply to *raw monochromatic LRO WAC EDRs* (so file names are something like M119428924ME.IMG). Processing colour WACs is another matter entirely. So let's begin.

1. Copy all your WACs to a single folder. Include the batch processing script `lrowac1` (given in Appendix 1) in the same folder. The script works on Linux Ubuntu Bash shell, but should, I guess, work on other Bourne shells as well, so Macs should be alright.

2. Give yourself the rights to execute the `lrowac1` batch processing script by typing in the terminal:

```
chmod 755 lrowac1
```

3. Execute the script by typing:

```
./lrowac1
```

The script includes all the level 0 and level 1 processing (hence the "1" in the name), so it includes ISIS programmes `lrowac2isis`, `spiceinit`, and `lrowaccal`, and it does these steps to both even and odd stripes (created by `lrowac2isis`) of all the WAC images in the folder. If the script for some reason doesn't work on your computer, you just have to do these steps manually, but it is a pretty straightforward procedure.

Note that script version of spiceinit uses the USGS SPICE web server instead of downloaded SPICE kernels, and the server requires you to have the current version of ISIS to work. A similar script is available for LRO NACs in Appendix 1, and the script can easily be modified for other datasets. I figured it out, so everyone else can do that as well.

4. I do photometric calibration (level 3 processing) at this stage because it seems to be faster at this stage rather than after map projection (level 2 processing). The folks who do this for a living seem to prefer to do it after map projection. But again, this is meant for photogeologic purposes and I haven't noticed any problems and, besides, my computer isn't the fastest, so I try to save processing time whenever I can. In any case, I have tested both ways, and they work.

In keeping with the “Beginner's guide”, I prefer to use the GUI rather than the command line. So run:

photomet

FROM is your even or odd stripe for which a radiometric calibration has already been done (using the lrowac1 script the resulting file names are *_even_cal.cub and *_odd_cal.cub), and the photometric calibration should of course be done to both of the stripes. TO is naturally the name of the resulting photometrically calibrated cube.

Now comes the interesting part. For some reason unknown to me, the PVL-files necessary for doing the photometric calibration of LRO WAC images, either monochromatic or colour, are not provided with ISIS, nor have I found them on the LROC website or anywhere else. However, using Clementine UVVIS “a” PVL-file, the results are good enough for photogeology. So in FROMPVL you should choose moon_clementine_uvvis_a.pvl file. This should be found in folder: /data/base/templates/photometry/

Keep the rest of the default settings and just run the programme for even and odd stripes.

5. If you haven't created a maptemplate yet, now is the time to do it. See the “Beginner's guide” for that.

6. After you have the map template, use it when you run cam2map for both even and odd stripes. Again, that's explained in the “Beginner's guide.”

7. Now you need to merge the even and odd stripes of the WAC image. First, a list of the even and odd stripe files is required. The list is a simple text file with the paths and file names, and it can be created with any text editor. I use Ubuntu's gedit. Here is an example of what a list file of even and odd WAC stripes can look like:

/home/d/Isis/Eimmart_A/WAC/728ME_even_cal_Clem-a_SC_676mpx.cub
/home/d/Isis/Eimmart_A/WAC/728ME_odd_cal_Clem-a_SC_676mpx.cub

So it is simply the paths of the even and odd stripe files that make the whole contents of the list file (you can name it *.txt or *.lis or whatever, it doesn't matter).

8. To create a mosaic of the even and odd stripes, I use noseam. FROMLIST is the list file that was just created, and TO is the final WAC image. Filter sizes HNS, HNL, LNS and LNL refer to high- and low-pass filters of lines and samples. The numbers entered for the filters *must* be odd. Keep the BandBin Option boxes checked. You can fiddle with the filter numbers all you want to find the best results. The minimum is 1, and the number cannot exceed twice the number of samples (for HNS and LNS) or lines (for HNL and LNL) of the image cube. For WACs I usually start by entering 333 for all the filters, and normally that gives an end result that is already perfectly satisfactory for my needs.

9. If you only had one WAC image to process, your job is finished now. Check with qview that it looks good and that the coordinates are correct. However, if you want to make a mosaic of WACs (level 4 processing), you need to create a list of the files that go into your mosaic. This is again done with a text editor like gedit, exactly the way the list of even and odd stripes was done. An important thing to keep in mind here is that the first image in the list is the topmost image of the resulting mosaic, the second image goes underneath it, and so forth. The actual mosaic is done with noseam, just like merging the even and odd stripes above. And after that, you’re done.

The final result should be a WAC mosaic that looks something like the first image in Appendix 2 on page 6. It is an example of a mosaic done very quickly with four WACs, using the procedure described above. The mosaic may not be perfect, but it is certainly usable for photogeologic work and publishable after fine tuning in Photoshop or whatever software one prefers to use. It is clearly superior to the mosaic on page 7, which was created without any photometric calibration. It also has some important advantages over an image cropped from the global WAC mosaic, shown on page 8. Thus, using the Clementine PVL-file for photometric calibration as a part of standard LRO WAC processing workflow is worth the little extra effort.

Appendix 1.

Here is the script lrowac1, which you can of course call it whatever you want, for batch processing (level 0 – level 1: lrowac2isis, spiceinit, lrowaccal) LRO WAC monochromatic images. Just copy and paste the script into your text editor and save it in the same folder with your raw images.

```
#!/bin/bash
# LRO WAC Mono Level 1 batch processing of raw images (.IMG)
# Copy this file to the folder where your raw images are
# Give yourself the permission to execute this file by typing: chmod 755 lrowac1
# Execute this file by typing: ./lrowac1
echo LRO WAC Mono Level 1 batch processing of raw images
ls *.IMG | sed s/.IMG// > cube.lis
lrowac2isis from=\$1.IMG to=\$1.cub -batchlist=cube.lis
spiceinit from=\$1.vis.even.cub web=yes -batchlist=cube.lis
spiceinit from=\$1.vis.odd.cub web=yes -batchlist=cube.lis
lrowaccal from=\$1.vis.even.cub to=\$1_even_cal.cub -batchlist=cube.lis
lrowaccal from=\$1.vis.odd.cub to=\$1_odd_cal.cub -batchlist=cube.lis
```

And here is a similar script lronac1 for LRO NACs, including ISIS programmes lronac2isis, spiceinit, lronaccal, and lronacecho. The lronacecho programme was not included in the “Beginner's guide”, because the NAC’s echo problem wasn't particularly widely publicised at the time, so I missed it then.

```
#!/bin/bash
# LRO NAC Level 1 batch processing of raw images (.IMG)
# Copy this file to the folder where your raw images are
# Give yourself the permission to execute this file by typing: chmod 755 lronac1
# Execute this file by typing: ./lronac1
echo LRO NAC Level 1 batch processing of raw images
ls *.IMG | sed s/.IMG// > cube.lis
lronac2isis from=\$1.IMG to=\$1.cub -batchlist=cube.lis
spiceinit from=\$1.cub web=yes -batchlist=cube.lis
lronaccal from=\$1.cub to=\$1_cal.cub -batchlist=cube.lis
lronacecho from=\$1_cal.cub to=\$1_cal_echo.cub -batchlist=cube.lis
```

Appendix 2.

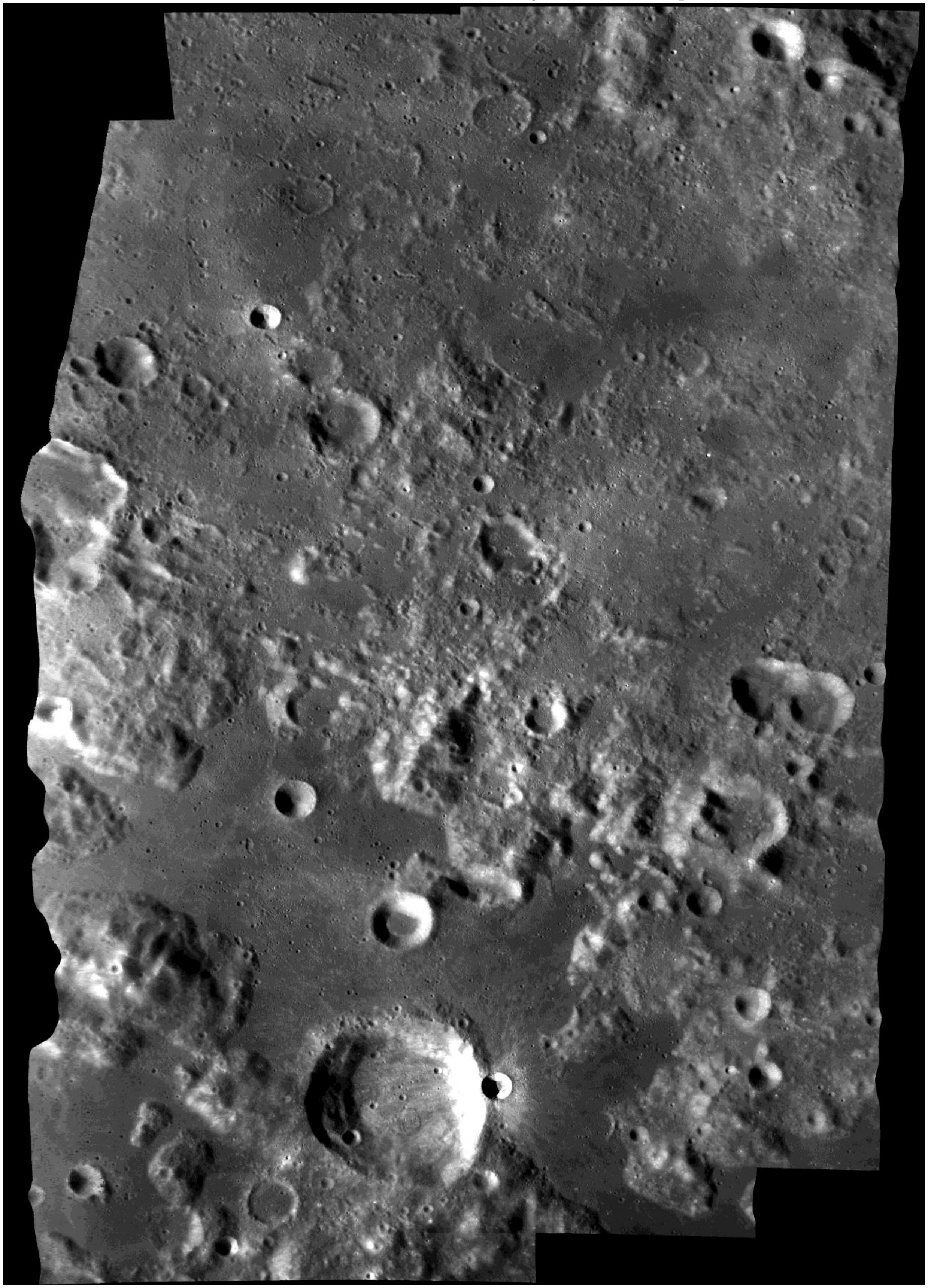
One might wonder why go through all that trouble of processing WAC images, when the ASU/LROC team already provides the wonderful global WAC mosaics (http://wms.lroc.asu.edu/lroc/view_rdr/WAC_GLOBAL)? Two reasons are obvious. Firstly, when processing images yourself, you get to use the full resolution of the images. The global WAC mosaics are made at a resolution of 100 m/pixel, whereas monochromatic WAC raw images have a resolution of about 55–70 m/pixel. Sometimes you might want to have that extra bit of resolution without having to use other datasets, like LRO NAC or Kaguya TC. Another important aspect is that although the global mosaics are very well done, you might get seams where you really wouldn't want to have them. When you create your own mosaics, you have much more control on everything, including where the seams are, and also how visible they are.

The image on the following page is a mosaic of LRO WAC images M119415370ME.IMG, M119422145ME.IMG, M119428924ME.IMG and M119435728ME.IMG from Eimmart region (the big crater (D=45 km) at the bottom, with fresh Eimmart A on its eastern rim), on the northern rim of Crisium basin. It was created using the procedure exactly as described above, including the photometric calibration utilising Clementine UVVIS "a" PVL-file. It is the first try, so even the filter values in noseam were my personal "default" values (333). Further tinkering would likely have improved the result to some extent. No Photoshopping was involved, so the image is just as it was after turning the image cube into a jpg-file with isis2std. The resolution of the original mosaic file is 67.6 m/pixel, and the projection is simple cylindrical.

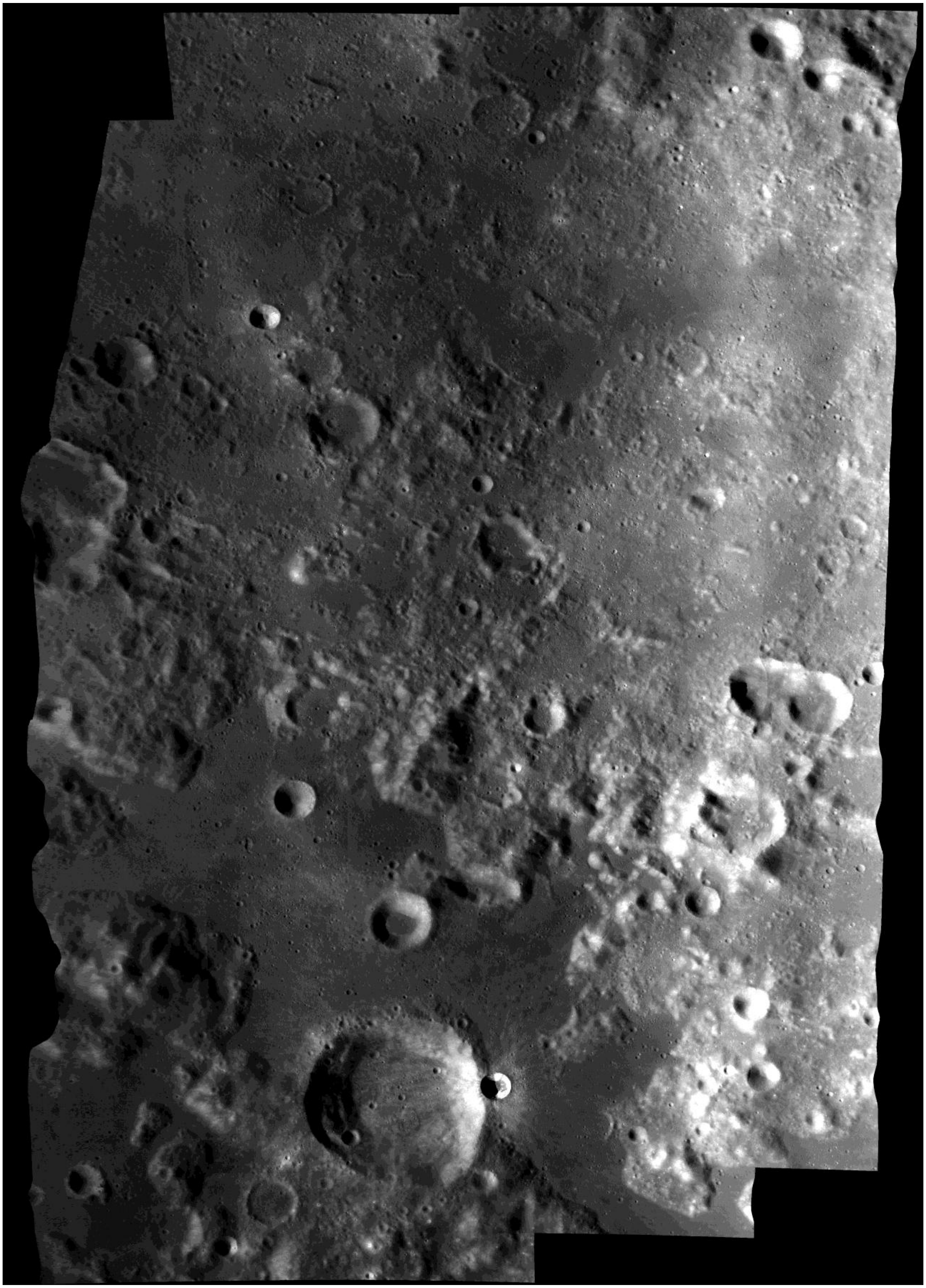
For comparison, page 7 shows exactly the same mosaic as the one on page 6, but created without applying any photometric calibration. The right side of the mosaic is far too bright, with many areas appearing completely over-exposed. Also some of the seams become more apparent. The benefits of photometric calibration, even when one is using WACs merely for photogeologic purposes, are quite obvious.

The image on the last page shows again the same Eimmart area, but now cropped from the ASU/LROC global WAC mosaic (100 m/pixel, simple cylindrical projection). The apparent differences between this and the first, self-made mosaic are subtle, but they are there. For example, if one was interested in Eimmart A's ejecta on Mare Anguis (just east of Eimmart A), the global mosaic's seam there is undesirable. Similarly, the global mosaic has practically all of Eimmart A's floor in shadow, while half of it is visible in the self-made one. In some other areas the global mosaic is clearly the better one, but the self-made mosaic was done particularly with Eimmart A in mind, so in other areas other images might have been used. In any case, it is clearly beneficial to have the option of creating your own WAC mosaics to complement the global ones.

A self-made mosaic of LRO WAC images M119415370ME.IMG, M119422145ME.IMG, M119428924ME.IMG and M119435728ME.IMG, using Clementine's photometric calibration file.



A mosaic otherwise similar to the one on the previous page, but made without any photometric calibration.



A cropped image of the global WAC mosaic's tile E300N0450, available at:
http://wms.lroc.asu.edu/lroc/view_rdr_product/WAC_GLOBAL_E300N0450_100M