LPGS / NLAPS Level 1 Product Radiometric Comparison

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Disclaimer – This document was created in May 2002, using data from that era. In March 2004, NLAPS changed their scaling so that their QCALMIN is now 1, duplicating the LPGS method. That change makes this document obsolete. A new LPGS/NLAPS comparison study will be available in spring/summer 2004.

Comparison Issues

LPGS and NLAPS level 1 products have several known radiometric differences:

- LPGS scales level 1 products to a range of 1-254 with values of 0 and 255 set aside to flag fill and high saturation, respectively. NLAPS scales images from 0 to 254, with a value of 0 DN used for both fill and the lowest radiance value in the scene.

- LPGS and NLAPS perform different sets of artifact corrections. This can cause minor, scene dependant differences in level 1 radiometry.

However a direct comparison between the products is only possible if there are no resampling differences -- relative radiometry for a pixel can only be analyzed if that pixel is guaranteed to be viewing the same area in both products. Because of differences in LPGS and NLAPS level 1 resampling, this guarantee cannot be made. The known resampling differences are:

- NLAPS trims the edge of ETM+ scenes. LPGS products contain all image data sampled, including the jagged scene edges and IC shutter intrusion at the end of each scan.

- 60 meter and 15 meter NLAPS and LPGS products have different image sizes. In general, the LPGS product contains one more line and sample than the corresponding NLAPS product for bands 6L, 6H, and 8.

- NLAPS and LPGS use different methods to align the bands. LPGS aligns the bands to the center of each pixel. NLAPS aligns bands to the edge of each pixel. This leads to differences in resampled product even if the resampling method were identical.

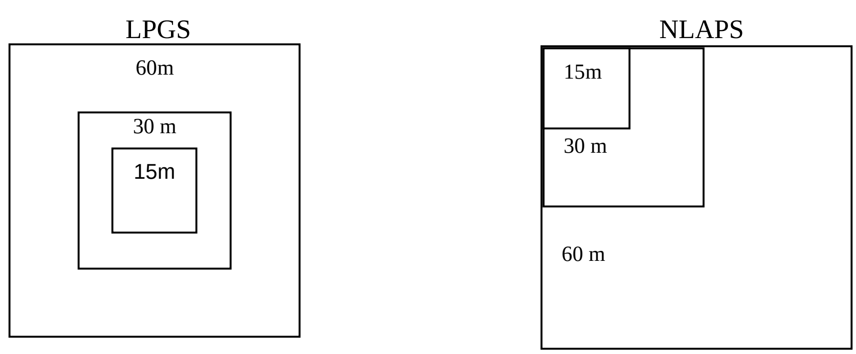


Figure 1. LPGS and NLAPS pixel alignment for 3 different resolutions.

- NLAPS and LPGS resampling methods are not identical. Analysis of geometric differences by Mike Choate revealed that the two systems use different ephemeris files as well as different algorithms to process quaternion, gyro, and gyro drift data.

These differences mean that even with the same L0 image and identical CPF parameters, LPGS and NLAPS will produce L1 products that cannot be directly compared radiometrically. Any sharp radiometric transitions in the scene will create pixels that appear bright to one processing system and dark to the other. Any radiometric comparison of LPGS and NLAPS images must involve homogenous regions without these sharp edges.

For radiometric comparison between images, a scatter plot is used. A comparison of identical data would show a thin line intersecting the origin with a slope of 1.

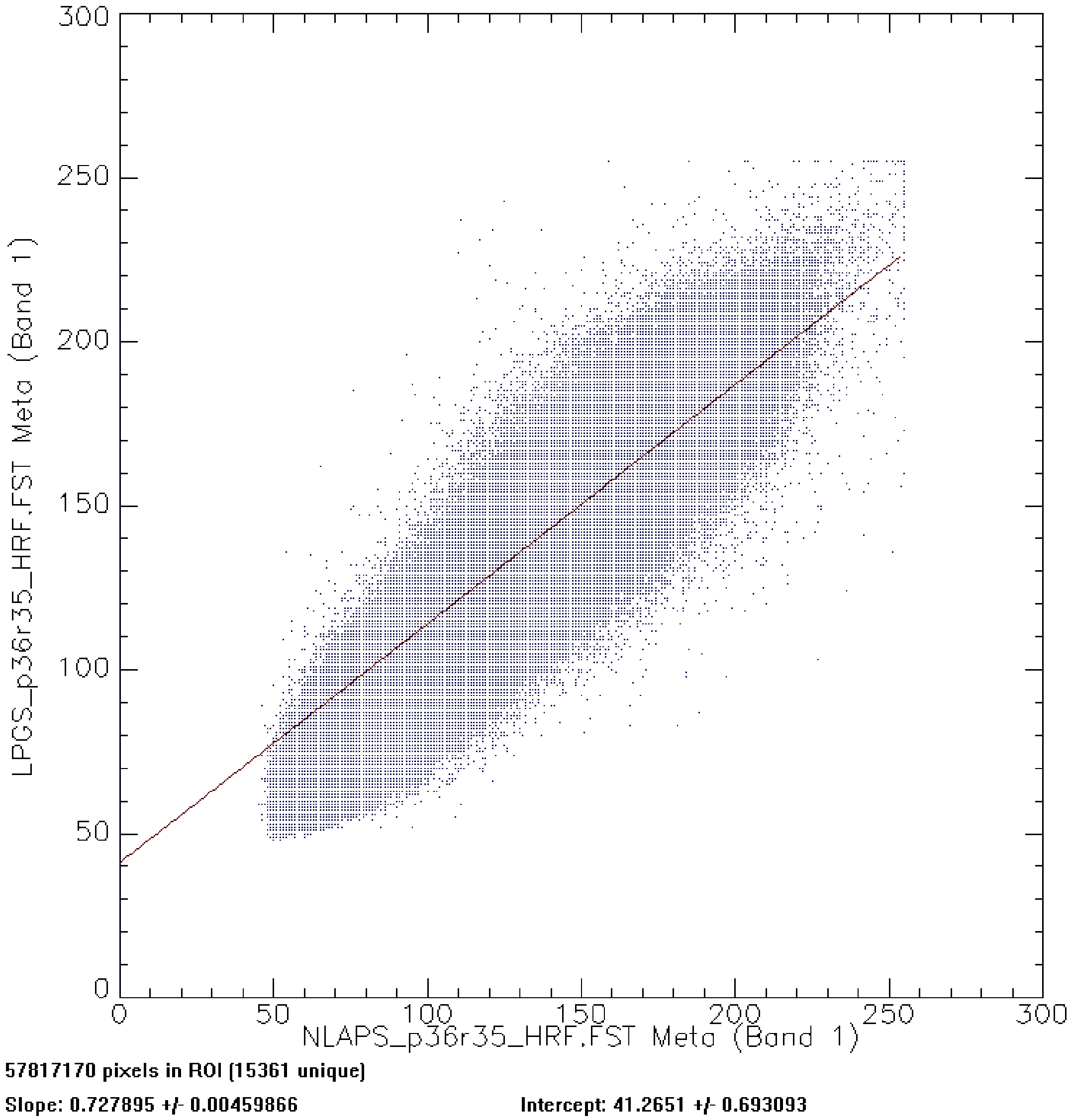


Figure 2: Full-scene scatter plot example

Figure 2 shows an example of a scatter plot between an entire LPGS L1 image and a corresponding NLAPS L1 image. A line has been fitted to the data using the IDL linear fit routine, which seeks a fit that minimizes the chi-square error statistic. The systems have resampled differently, spoiling the comparison.

Methodology

To compare the two processing systems, homogenous regions within a set of 7 test images were constructed. These regions of interest were chosen for homogenaity (less than 5 DN standard deviation over the region, for all bands) and dynamic range (selected regions cover the range of radiances in the scene, for all bands). The datasets chosen were a subset of the geometric test scenes from Choate's study, for which LPGS and NLAPS level 1 products were available.

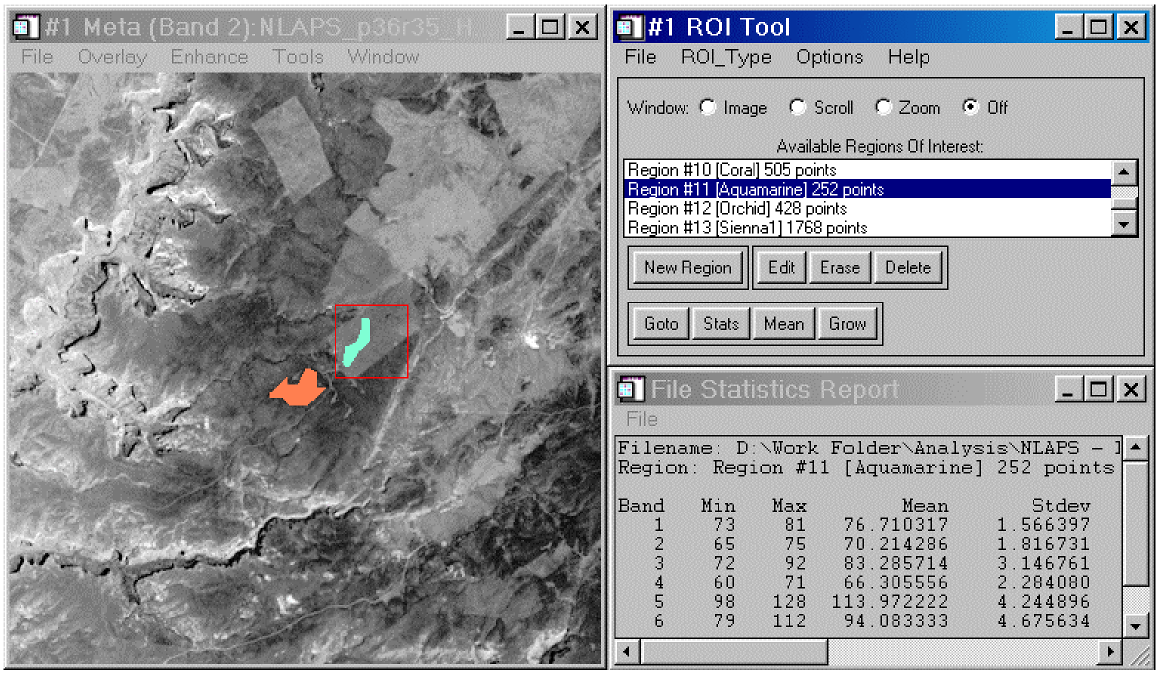


Figure 3: Regions of interest selection.

The scatter plot of the regions of interest for a scene create a line upon which a linear fit can be applied. Scatter plots were created using an IDL procedure written for this purpose and added onto ENVI. The procedure, scatter_compare.pro, is included at the end of this document.

The parameters of the linear fit provide a measure of the relative gain and bias between LPGS and NLAPS L1 products. Figure 4 shows an example of a scatter plot over selected homogenous regions of interest. The scatter_compare procedure automatically performs a linear fit to the scatter data, and estimates the standard deviation of the data around the fitted slope and intercept.

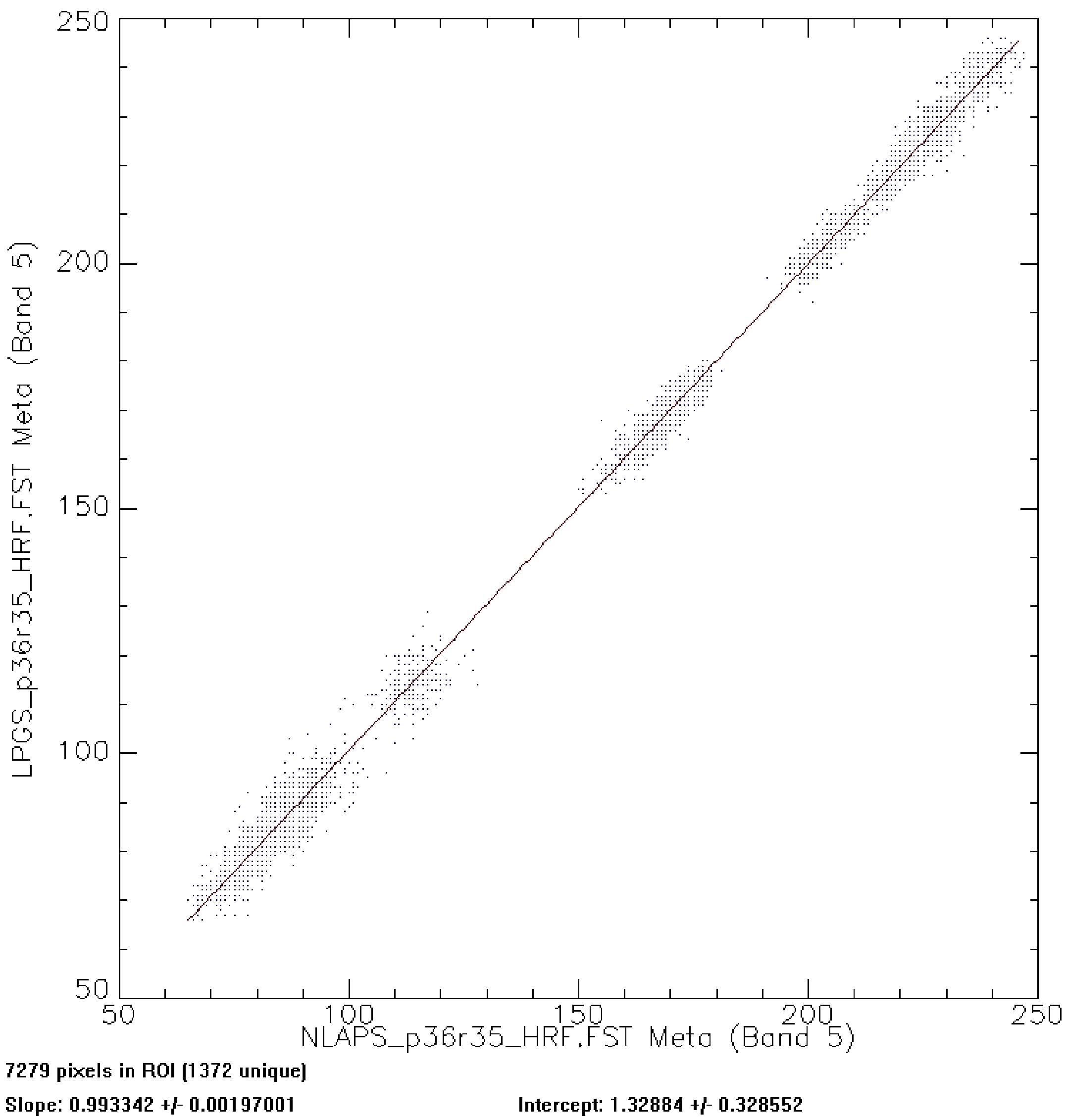


Figure 4: ROI scatter plot example

Path/Row	Band	Slope	+/-	Intercept	+/-
18/37	1	0.993982	0.002650	1.036480	0.374262
18/37	2	0.995753	0.002580	0.869825	0.337787
18/37	3	0.993324	0.002509	0.754966	0.368596
18/37	4	0.925745	0.012312	7.504690	1.090710
18/37	5	0.984788	0.004102	1.520060	0.430940
18/37	7	0.991564	0.003223	0.702618	0.345003
18/37	6L	0.988461	0.013467	2.288120	1.806320
18/37	6H	0.994009	0.007397	1.371340	1.296110
18/37	8	0.990106	0.003780	2.394740	0.415988
16/40	1	0.981596	0.005349	2.525970	0.554959
16/40	2	0.992031	0.004133	1.370750	0.341752
16/40	3	0.992931	0.003241	1.140020	0.264474
16/40	4	0.993551	0.005155	1.058380	0.439074
16/40	5	0.997023	0.003228	0.686031	0.314908
16/40	7	0.999416	0.003946	0.667124	0.265498
16/40	6L	0.987526	0.010199	2.173440	1.393470
16/40	6H	0.997157	0.005502	0.562944	0.883075
16/40	8	1.008720	0.005315	0.422878	0.438768
36/35	1	0.989685	0.004689	1.582260	0.521597
36/35	2	0.992543	0.003184	1.355860	0.360863
36/35	3	0.995176	0.001731	1.051940	0.268423
36/35	4	0.995527	0.003952	0.913183	0.369899
36/35	5	0.993342	0.001970	1.328840	0.328552
36/35	7	0.991729	0.001847	1.533820	0.274253
36/35	6L	0.988665	0.005409	1.989310	0.852254
36/35	6H	0.992167	0.003314	1.052940	0.672575
36/35	8	0.983856	0.004083	1.698020	0.428656
29/29	1	1.011950	0.008294	-0.080727	0.769494
29/29	2	1.010450	0.006900	0.200294	0.546899
29/29	3	0.998113	0.005637	1.058740	0.467296
29/29	4	1.000420	0.003130	0.839162	0.348107
29/29	5	0.997469	0.003076	1.185750	0.475721
29/29	7	0.998303	0.003534	1.031040	0.408738
29/29	6L	0.996261	0.004789	1.034860	0.688335
29/29	6H	0.997581	0.002890	0.614447	0.510128
29/29	8	1.004800	0.003953	0.608731	0.321459
30/36	1	0.988773	0.006913	1.585840	0.621075
30/36	2	0.993529	0.004031	1.057500	0.330304
30/36	3	0.995304	0.001919	1.092190	0.188724
30/36	4	0.995933	0.003341	1.005510	0.226899
30/36	5	0.995980	0.001908	0.910242	0.284530
30/36	7	0.997170	0.001834	0.816054	0.222309
30/36	6L	0.988575	0.003692	2.109070	0.564017
30/36	6H	0.991466	0.002044	1.455120	0.389903
30/36	8	0.995410	0.003823	1.077330	0.344243
39/37	1	0.982705	0.006304	2.507680	0.700358
39/37	2	0.981635	0.006198	2.505560	0.675063
39/37	3	0.985956	0.004601	2.475910	0.617884
39/37	4	0.987090	0.005102	2.021790	0.506676
39/37	5	0.981722	0.006143	2.794870	0.746930
39/37	7	0.983185	0.005685	2.494030	0.600251
39/37	6L	0.998726	0.002223	0.023556	0.279515
39/37	6H	0.998012	0.001159	-0.474871	0.172226
39/37	8	0.994945	0.002481	1.248840	0.319332
30/33	1	0.993694	0.004476	1.171290	0.477794
30/33	2	0.993177	0.003734	1.374810	0.379214
30/33	3	0.996968	0.002256	0.913679	0.280509
30/33	4	0.994605	0.002308	1.059360	0.254525
30/33	5	0.996450	0.001771	1.027930	0.300727
30/33	7	0.995250	0.001889	1.101080	0.282655
30/33	6L	0.985273	0.007429	2.759290	1.129610
30/33	6H	0.991688	0.003960	1.732110	0.752674
30/33	8	0.992509	0.003766	1.211330	0.343694

Table 1: Line fit parameters

Results

The results of line fitting to ROI scatter plots for the 7 test scenes is displayed in Table 1.

Table 2 is a distillation of Table 1, showing the mean slope and intercept for each band along with the number of standard deviations from the mean slope and intercept for four possible outcomes. These outcomes are displayed in the plots in Figures 5 and 6. LPGS and NLAPS agree to within a scaling difference of 0.65%.

The relative gain and bias between LPGS and NLAPS level 1 radiometry is consistent with the expected range ratio of 254/255 and the expected bias of 1. This creates a 0.4% scaling difference between LPGS and NLAPS. Converting both scenes to radiance units would correct for this difference in scaling.

There appears to be a net 0.25% scaling difference, with LPGS scenes having systematically lower radiance than NLAPS scenes. This difference is likely due to the differences in radiometric processing between the two systems.

Neglecting one outlier in Band 4 (probably caused by an inhomogenous region of interest; due to vegetation, Band 4 is the most challenging band to analyze in this way), the maximum scaling difference between LPGS and NLAPS was 1.8% (1.4% corrected for known processing differences). All bands except band 5 met a 95% confidence value t-test for a slope of 254/255 and an intercept of 1.

	Slope		Intercept		Number of samples	t value				t-test 95% confidence value
	Mean	Std. Dev.	Mean	Std. Dev.		Slope = 1	Slope = 254/255	Intercept = 0	Intercept = 1	
Band 1	0.9918	0.0055	1.4755	0.5742	7	3.9415	**2.0635**	6.7986	**2.1911**	2.4469
Band 2	0.9942	0.0044	1.2478	0.4246	7	3.5164	**1.1552**	7.7761	**1.5442**	2.4469
Band 3	0.9940	0.0031	1.2125	0.3508	7	5.1030	**1.7857**	9.1435	**1.6024**	2.4469
Band 4	0.9945	0.0038	1.1496	0.3575	6	3.5029	**0.9957**	7.8758	**1.0247**	2.5706
Band 5	0.9924	0.0032	1.3505	0.4118	7	6.3443	3.0723	8.6778	**2.2523**	2.4469
Band 6L	0.9905	0.0067	1.7682	0.9591	7	3.7277	**2.1892**	4.8779	**2.1193**	2.4469
Band 6H	0.9946	0.0038	0.9020	0.6681	7	3.8197	**1.0546**	3.5720	**0.3881**	2.4469
Band 7	0.9938	0.0031	1.1923	0.3427	7	5.2272	**1.9197**	9.2053	**1.4844**	2.4469
Band 8	0.9958	0.0039	1.2374	0.3732	7	2.8844	**0.2143**	8.7733	**1.6833**	2.4469
Reflective Bands	0.9934	0.0039	1.2743	0.4115	41	4.5112	**1.8269**	8.1924	**1.7636**	2.0211
Thermal Bands	0.9925	0.0052	1.3351	0.8136	14	3.7606	**1.7836**	4.3418	**1.0898**	2.1604
Pan Band	0.9958	0.0039	1.2374	0.3732	7	2.8844	**0.2143**	8.7733	**1.6833**	2.4469
All Bands	0.9935	0.0042	1.2839	0.4980	62	4.1277	**1.6453**	6.8210	**1.5083**	1.9996

Table 2: Line Fit Statistics by Band

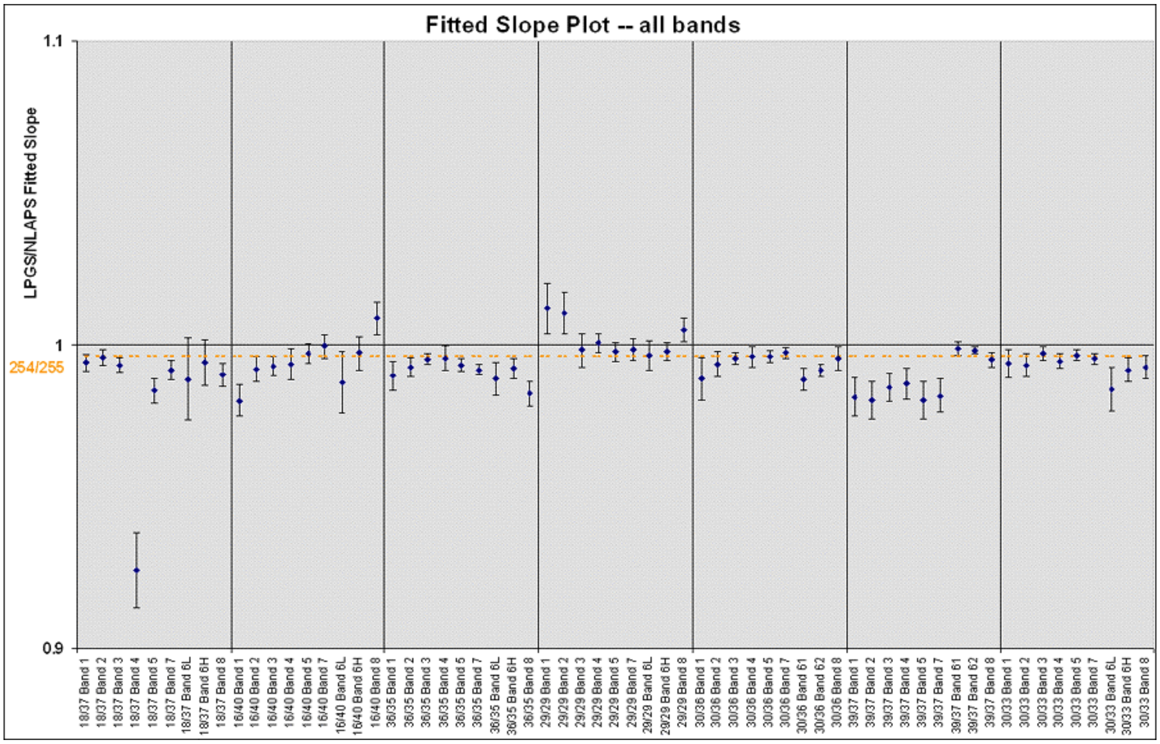


Figure 5: Mean Slope Plot -- test of relative gains.

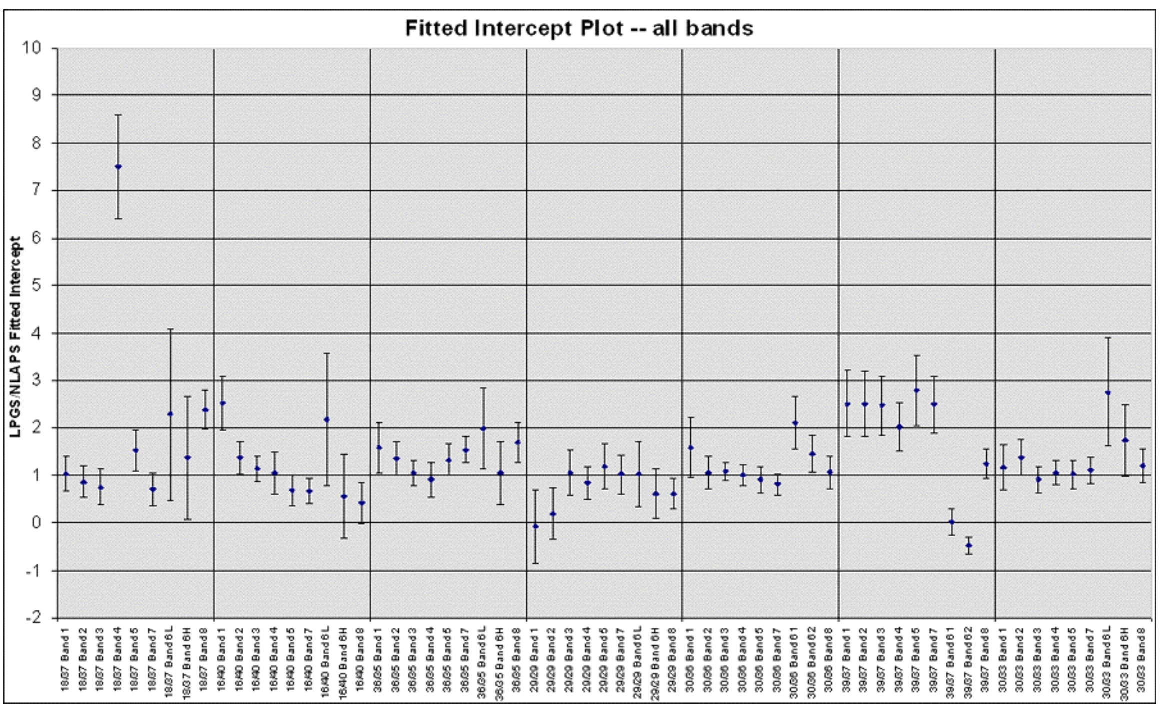


Figure 6: Mean Intercept Plot -- test of relative bias.

Summary

LPGS and NLAPS level 1 products agree to within a scaling factor of 1.8%, with an average difference of 0.65%.

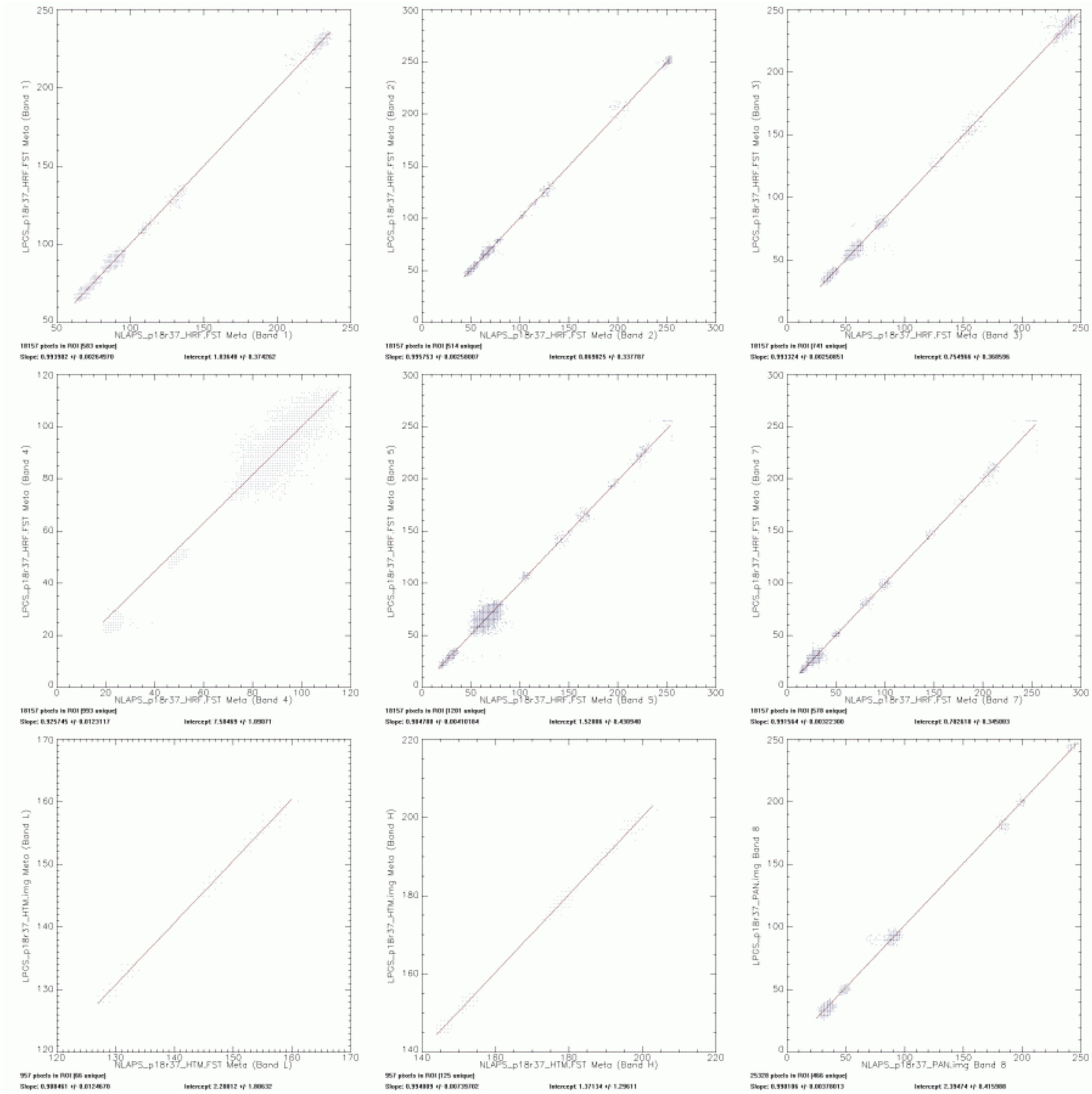
The known differences in scaling account for 0.4%, but this difference is corrected when the product is converted to radiance units. This reduces the net difference to a mean of 0.25% and a worst-case difference of 1.4%.

These are differences in scaling factor or gain, and are thus not easily translated into DN. At a maximum DN count of 255, the mean difference of 0.25% will result in a 0.6 DN difference. At a DN count of 10 (the detector bias in most bands) the mean difference of 0.25% will result in a 0.025 DN difference.

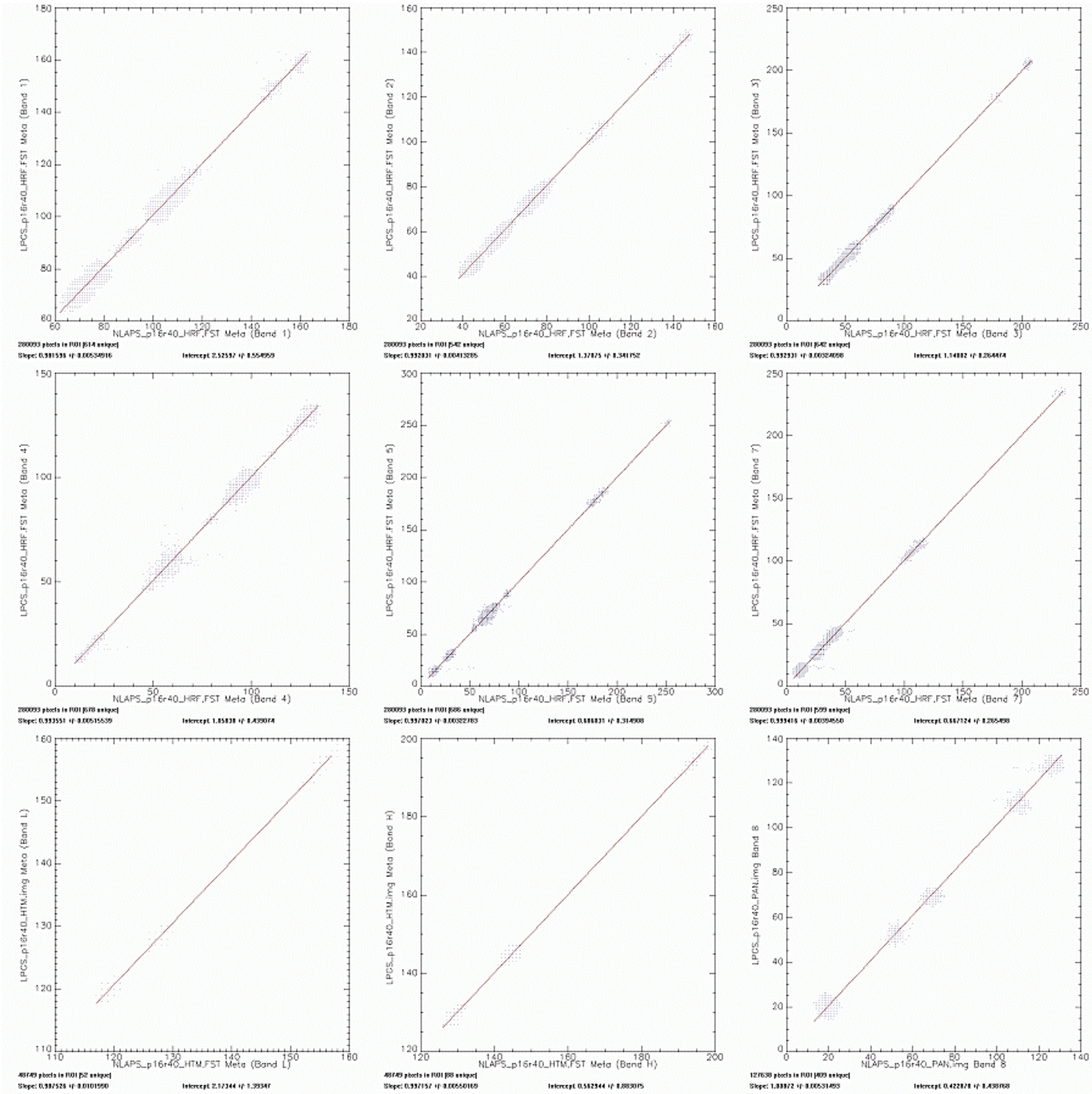
The net difference after conversion to radiance appears to be systematic, with LPGS lower than NLAPS by 0.25%. Because all bands passed the t-test for bias, this systematic difference is likely to be a scaling difference between the two systems.

The datasets analyzed are consistent with the expected gain ratio of 254/255 and bias of 1 DN.

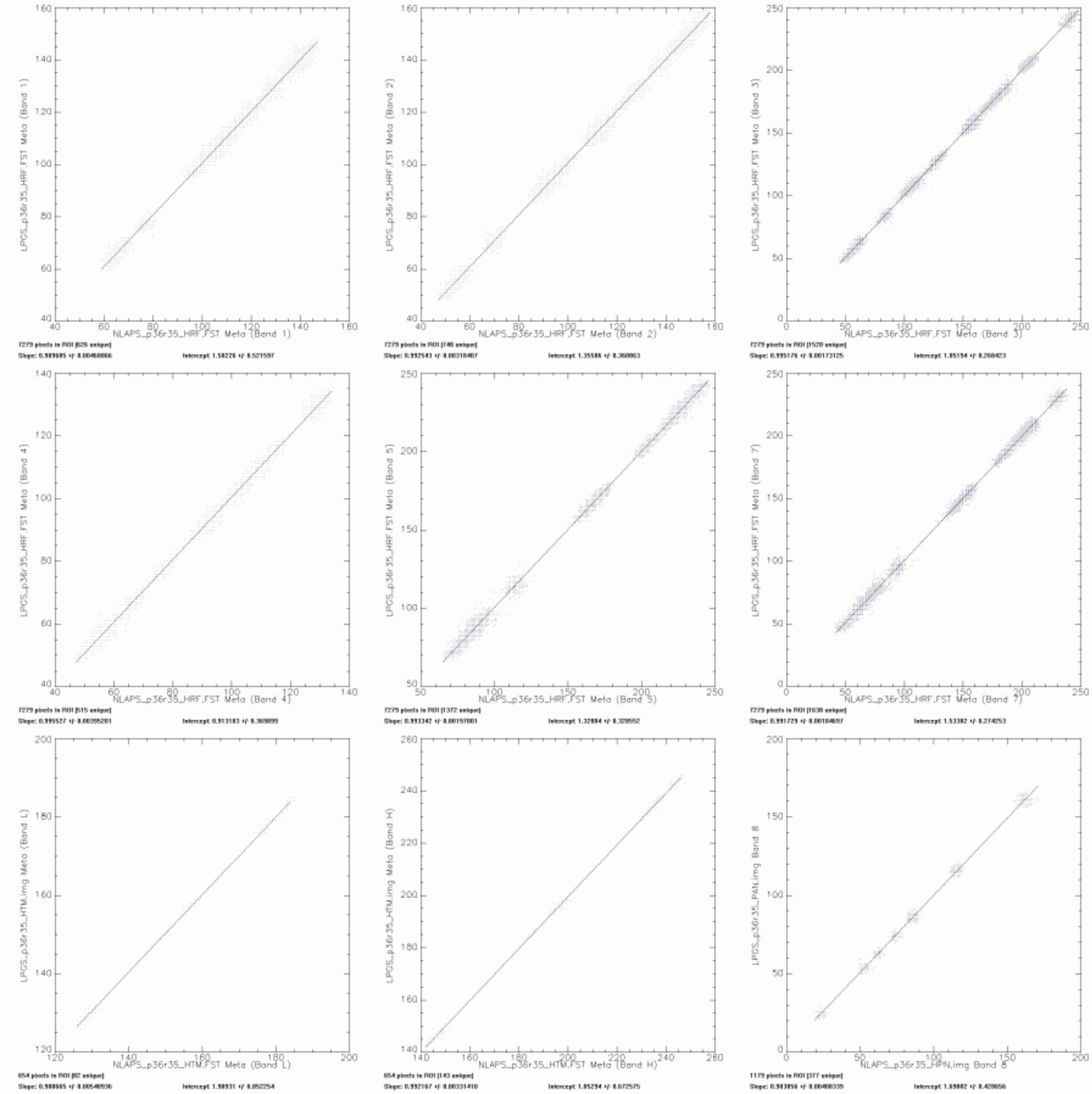
Appendix A: Scatter plots



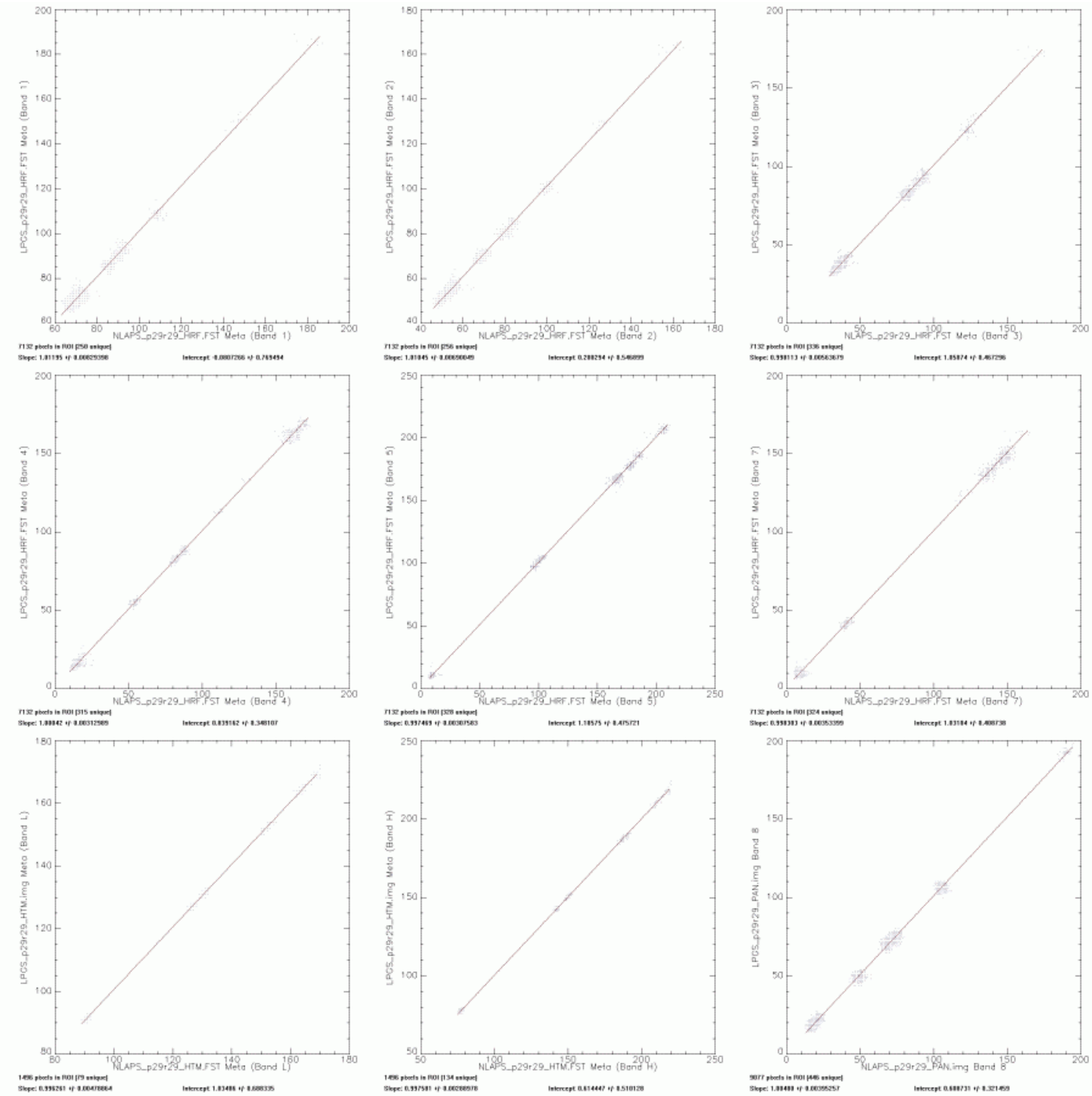
Path 18
Row 37
Acquired 6/22/2001



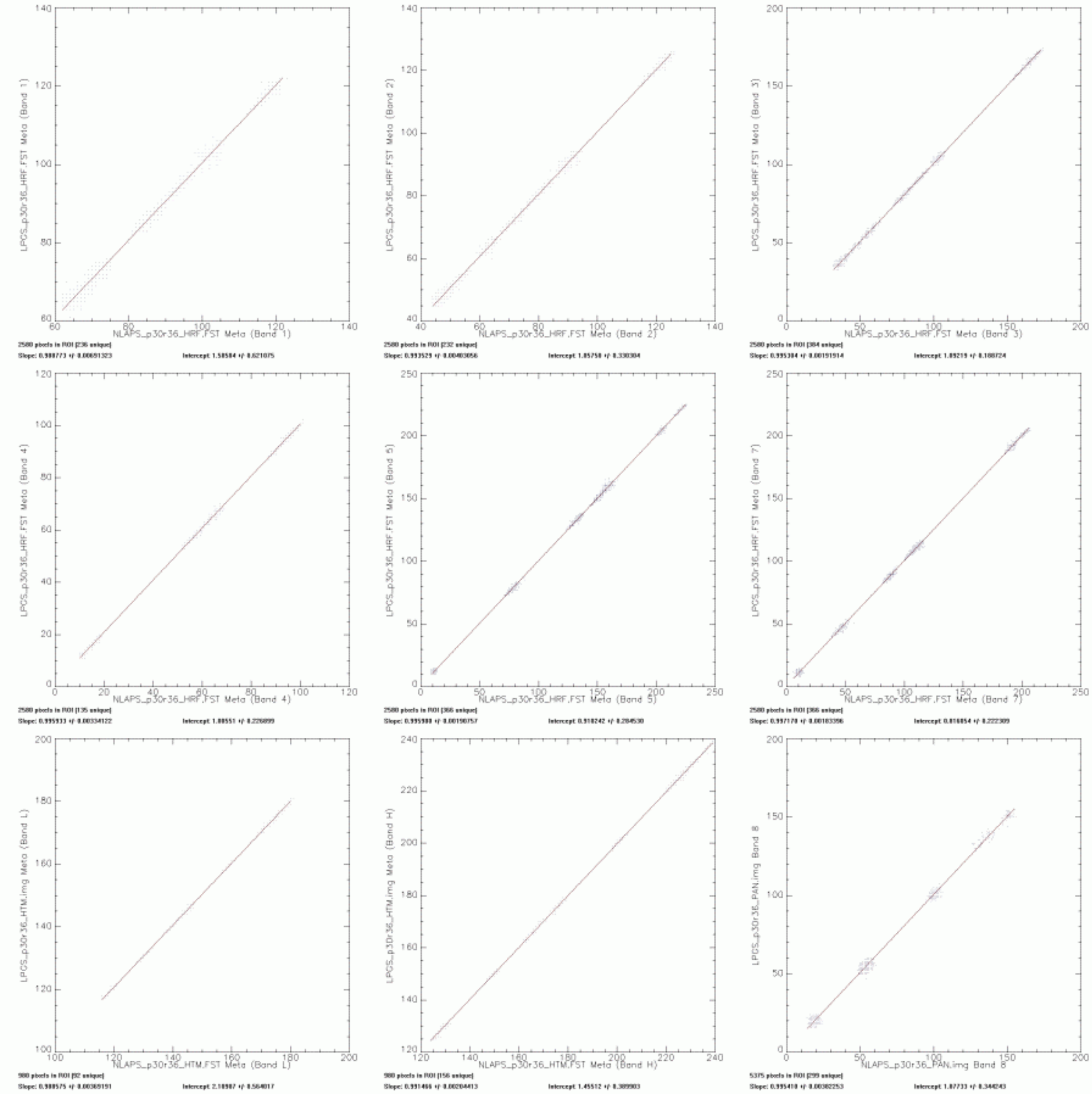
Path 16
Row 40
Acquired 4/3/2001



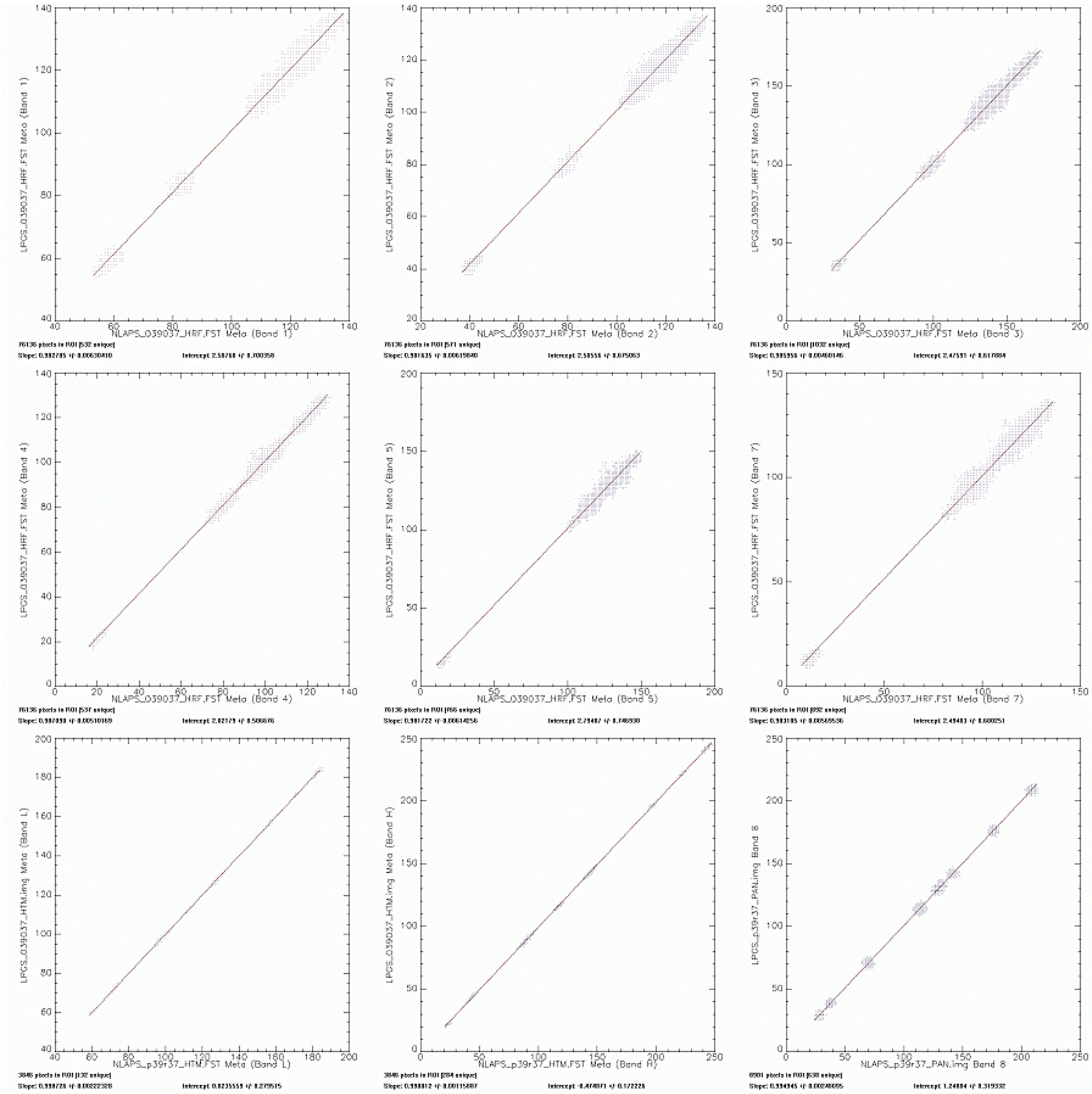
Path 36
Row 35
Acquired 6/15/2000



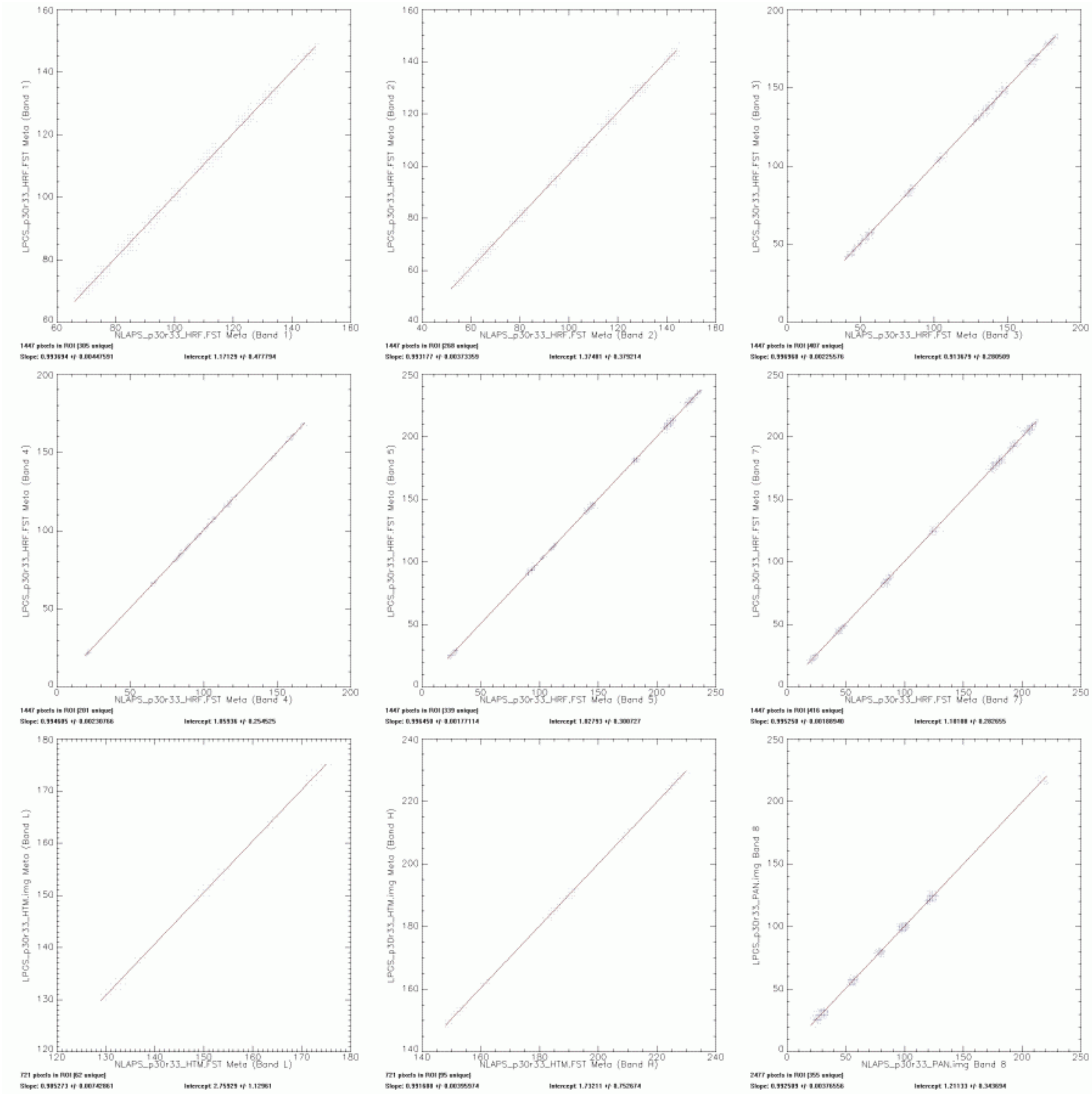
Path 29
Row 29
Acquired 6/3/2001



Path 30
Row 36
Acquired 4/18/2000



Path 39
Row 37
Acquired 6/22/2000



Path 30
Row 33
Acquired 6/7/2000

Appendix B: scatter_compare.pro

```
function truecolor, r, g, b

   return, long(b)*256L*256L+long(g)*256L+long(r)

END

PRO scatter_compare, event

envi_select, title="Select X axis data", fid=scafid1, $
      dims=scadims1, pos=scapos1, /roi
envi_select, title="Select Y axis data", fid=scafid2, $
      dims=scadims2, pos=scapos2, /roi

; Get a name to use for these data sets.
envi_file_query, scafid1, bnames=scanames1, fname=fname1, sname = sname1
envi_file_query, scafid2, bnames=scanames2, fname=fname2, sname = sname2


IF (scadims1[0] ne -1) THEN BEGIN

   ; Region of interest selected.

   ; Iterate over the selected bands.

   FOR band=0, n_elements(scapos1)-1 DO BEGIN

      print, "Getting data for band "+STRTRIM(scapos1[band],2)+" : ", systime()

      util = envi_get_roi_ids()
      data1 = envi_get_roi_data(util[scadims1[0]], $
         fid=scafid1, pos=scapos1[band])
      data2 = envi_get_roi_data(util[scadims2[0]], $
         fid=scafid2, pos=scapos2[band])

      print, "Data has been read: ", systime()

      ; We want only unique x,y combinations, for speed.

      xdata = data1[0]
      ydata = data2[0]

      FOR x=fix(min(data1)), fix(max(data1)) DO BEGIN
         xfound = where(data1 eq x)
         IF (xfound[0] ne -1) THEN BEGIN
            FOR y=fix(min(data2)), fix(max(data2)) DO BEGIN
               util = where(data2[xfound] eq y)
               IF (util[0] ne -1) THEN BEGIN
                  xdata = [xdata, x]
                  ydata = [ydata, y]
               ENDIF
            ENDFOR
         ENDIF

      ENDFOR

      print, "Plot created: ", systime()

      util = [ min(min([xdata, ydata])), max(max([xdata, ydata])) ]

      window, 0, retain=2, xsize=800, ysize=800
```

```
      plot, xdata, ydata, /nodata, /ynozero, $
         xtitle = sname1 + ' ' + scanames1[scapos1[band]], $
         ytitle = sname2 + ' '+ scanames2[scapos2[band]], $
         xrange = util, yrange = util, /iso, ymargin = [8, 1], $
         background = truecolor(255, 255, 255), color=0
      oplot, xdata, ydata, color=truecolor(64, 0, 0), psym=3

      ; Make a linear fit of the data.

      util = linfit(xdata, ydata, prob=fitprob, chisq = fitchi, $
         sigma = fitsigma, measure_errors = fitmeasure)
      fita = util[0]
      fitb = util[1]

      ; Plot the fitted line.
      util = findgen(max(xdata)-min(xdata))+min(xdata)
      oplot, util, fitb*util+fita, color=truecolor(0, 0, 80)

      xyouts, 0.05, 0.05, STRTRIM(n_elements(data1),2)+ $
         " pixels in ROI ("+STRTRIM(n_elements(xdata),2)+" unique)", $
         color=0, /norm, charsize=0.6, font=0

      xyouts, 0.05, 0.02, "Slope: "+STRTRIM(fitb,2)+ $
         " +/- "+STRTRIM(fitsigma[1],2), $
         color=0, /norm, charsize=0.6, font=0
      xyouts, 0.5, 0.02, "Intercept: "+STRTRIM(fita,2)+ $
         " +/- "+STRTRIM(fitsigma[0],2), $
         color=0, /norm, charsize=0.6, font=0

      ; Get the file name, and save the plot.
      util = STRMID(sname1, STRPOS(sname1, '_'), $
         RSTRPOS(sname1, '.')-STRPOS(sname1, '_'))
      print, "Saving plot as "+ $
         STRMID(fname1,0,RSTRPOS(fname1,'\')+1)+'nl'+util+'_b'+ $
         STRTRIM(scapos1[band],2)+'.tif'
      write_tiff, STRMID(fname1,0,RSTRPOS(fname1,'\')+1)+ $
         'nl'+util+'_b'+STRTRIM(scapos1[band],2)+'.tif', $
         reverse(tvrd(/true), 1), 0
   ENDFOR
ENDIF
END
```