Know the Earth…Show the Way

Assessment of SRTM X-Band Data for C-Band Void Fill

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Purpose

- To evaluate the feasibility of using the SRTM X-band terrain data for void fill in NGA's SRTM C-band DTED® Lv2 Void-Fill program.

Background

- 23 one-degree cells of German X-band terrain data were obtained for comparative analysis to C-band DTED® Lv2.
- X-band cell locations
  - 9 cells in north Africa
  - 6 cells in Germany
  - 4 cells in Afghanistan-Pakistan
  - 4 cells in South America
- All X-band data were delivered in 15'x15' sub-cell units, and were merged together to create one-degree cells.

Methods

- Statistical information was compiled. This includes general data set statistics, spike/well counts, void pixel counts, comparisons to GCPs, vertical and horizontal differences between X and C-band.
- Visual analysis.

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Statistical Evaluation, Africa 9 cells

Data Set or Cell I.D.	Relief Type	Min./Max.	Std. Dev.	Spike & well Min./Max.	# Void Pixels	% Void	# GCPs used	GCP Mean	GCP L.E. @90%	Difference Min./Max.	Difference Mean	Difference Std. Dev.	DAT Overall Horz. Bias
Africa 9 cells Cband	Low	244 / 507	22.65	-89 / 66	46802603	40.12							
Africa 9 cells Xband	Low	-33 / 876	21.18	-309 / 444	77923583	66.79				-379 / 386	-3.261	12.419	
Africa 9 cells common void	Low				34814559	29.8							
W010N19 Cband	Low	322 / 461	9.93	-40 / 50	2677904	20.7	14	2.3	7.1				
W010N19 Xband	Low	165 / 675	14.66	-212 / 251	7427463	57.3	0	NA	NA	-264 / 239	-0.83	13.76	
W009N19 Cband	Low	281 / 456	12.12	-49 / 45	6883557	53.1	0	NA	NA				
W009N19 Xband	Low	-5 / 876	17.25	-309 / 444	6970512	53.8	0	NA	NA	-379 / 314	-3.78	14.15	
W008N19 Cband	Low	244 / 424	6.28	-52 / 45	4207278	32.5	211	5.0	12.0				
W008N19 Xband	Low	98 / 688	10.94	-190 / 288	10166053	78.4	72	15.9	28.3	-230 / 205	-10.13	10.69	
W010N20 Cband	Low	325 / 478	10.61	-48 / 57	2846121	22.0	61	4.3	9.2				
W010N20 Xband	Low	-33 / 772	15.44	-293 / 317	6563767	50.6	37	8.7	19.0	-331 / 386	-1.97	13.51	
W009N20 Cband	Low	310 / 466	11.38	-55 / 46	4825222	37.2	8	4.0	12.0				
W009N20 Xband	Low	123 / 647	13.07	-189 / 233	6229807	48.0	3	6.4	12.3	-250 / 185	-3.47	9.42	
W008N20 Cband	Low	282 / 428	14.06	-46 / 46	6952048	53.6	79	2.3	9.0				
W008N20 Xband	Low	165 / 494	36.84	-113 / 107	12965417	99.99	0	NA	NA	NA	NA	NA	
W010N21 Cband	Low	281 / 454	15.54	-89 / 58	5583895	43.1	6	4.4	8.4				
W010N21 Xband	Low	-2 / 737	18.88	-268 / 280	8587273	66.2	4	6.3	14.6	-273 / 249	-2.40	11.54	
W009N21 Cband	Low	244 / 507	16.77	-74 / 66	7576681	58.4	2	0.8	7.9				
W009N21 Xband	Low	-10 / 734	15.76	-233 / 289	10336445	79.7	0	NA	NA	-196 / 187	-4.98	9.90	
W008N21 Cband	Low	258 / 433	13.89	-44 / 54	5273870	40.7	2	1.9	10.2				
W008N21 Xband	Low	3 / 741	23.28	-290 / 304	8707462	67.2	1	-4.3	NA	-318 / 292	-3.03	11.52	

Values in meters.

"Difference" statistics generated by subtracting X-band from C-band (C-band - X-band).

"DAT" statistics generated by using C-band as truth and X-band as test.

GCP = Ground Control Point (NGA generated).

DAT = DEM Analysis Tool (GOTS s/w).

NA = Not Available

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Statistical Evaluation, Germany 6 cells

Data Set or Cell I.D.	Relief Type	Min./Max.	Std. Dev.	Spike & well Min./Max.	# Void Pixels	% Void	# GCPs used	GCP Mean	GCP L.E. @90%	Difference Min./Max.	Difference Mean	Difference Std. Dev.	DAT Overall Horz. Bias
Germany 6 cells Cband	med	163/3686	571.37	-99/99	1779684	2.29							
Germany 6 cells Xband	med	-29/3478	563.35	-386/422	27789966	35.73				-776/592	-2.25	19.96	
Germany 6 cells common void	med				841712	1.08							
E007N47 Cband	low	163/1622	255.27	-50/53	4441	0.03	154	.14	7.15				
E007N47 Xband	low	-29/1624	272.67	-307/379	3517452	27.13	118	2.46	9.31	-573/364	-3.62	8.68	
E008N47 Cband	low	286/2862	245.23	-91/94	28392	0.22	186	1.69	7.20				
E008N47 Xband	low	144/2887	270.95	-368/383	3230418	24.91	133	4.21	11.00	-545/414	-3.08	11.00	
E009N47 Cband	med	372/2952	427.78	-98/99	183829	1.42	69	-.52	8.02				
E009N47 Xband	med	237/2998	487.54	-337/422	5096898	39.31	53	-1.39	8.10	-776/592	-2.95	25.00	
E010N47 Cband	med	569/3397	558.40	-99/98	400582	3.09	57	.59	8.10				
E010N47 Xband	med	442/3407	519.90	-321/341	2374550	18.31	52	-1.54	10.34	-625/551	-0.92	21.44	
E011N47 Cband	high	472/3477	613.85	-98/93	640818	4.94	69	-2.20	15.43				
E011N47 Xband	high	347/3478	684.16	-386/415	7688375	59.29	28	-8.39	21.10	-746/560	-2.20	29.33	
E012N47 Cband	high	376/3686	678.17	-99/98	521969	4.03	40	-1.66	8.38				
E012N47 Xband	med	275/3293	533.58	-317/378	5889078	45.42	23	-3.94	11.30	-567/540	-0.43	23.27	
E00745N4730													4.74 N.W.
E00830N4700													18.07 N.E.
E00930N4700													23.56 N.W.
E01030N4715													18.55 N.E.
E01130N4700													17.63 N.W.
E01200N4715													14.77 N.W.

Values in meters.

"Difference" statistics generated by subtracting X-band from C-band (C-band - X-band).

"DAT" statistics generated by using C-band as truth and X-band as test.

GCP = Ground Control Point (NGA generated).

DAT = DEM Analysis Tool (GOTS s/w).

NA = Not Available

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Statistical Evaluation, Afghanistan-Pakistan 4 cells

Data Set or Cell I.D.	Relief Type	Min./Max.	Std. Dev.	Spike & well Min./Max.	# Void Pixels	% Void	# GCPs used	GCP Mean	GCP L.E. @90%	Difference Min./Max.	Difference Mean	Difference Std. Dev.	DAT Overall Horz. Bias
Afg-Pak 4 cells Cband	high	583/7025	953.66	-99/+99	10568444	20.4							
Afg-Pak 4 cells Xband	high	523/6846	935.83	-493/+720	33909197	65.4				-963/+922	-6.29	39.79	
Afg-Pak 4 cells common void	high				8303316	16.0							
E072N35 Cband	high	583/6158	1019.73	-99/+98	2844414	21.9	115	-2.33	14.81				
E072N35 Xband	high	523/5761	1007.24	-493/+611	9834097	75.8	31	-2.86	24.86	-875/+780	-6.88	40.42	
E072N36 Cband	high	1690/7025	836.92	-99/+99	2840852	21.9	91	-1.34	14.61				
E072N36 Xband	high	2629/6846	783.79	-447/+493	9848367	75.9	30	1.08	29.43	-719/+847	-8.59	38.11	
E073N35 Cband	high	656/5666	972.38	-98/+99	2826371	21.8	97	2.44	17.06				
E073N35 Xband	high	650/5376	833.94	-442/+606	8012960	61.8	25	-2.78	34.65	-887/+663	-4.17	31.39	
E073N36 Cband	high	1717/6458	775.75	-97/+98	2059688	15.9	58	2.70	17.51				
E073N36 Xband	high	1604/6559	817.76	-483/+720	6222436	48.0	33	-1.79	68.67	-963/+922	-6.55	45.30	
E07330N3600 Xband													8.99 N.E.

Values in meters.

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"DAT" statistics generated by using C-band as truth and X-band as test.

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NA = Not Available

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Statistical Evaluation, South America 4 cells

Data Set or Cell I.D.	Relief Type	Min./Max.	Std. Dev.	Spike & well Min./Max.	# Void Pixels	% Void	# GCPs used	GCP Mean	GCP L.E. @90%	Difference Min./Max.	Difference Mean	Difference Std. Dev.	DAT Overall Horz. Bias
S. Amer. 4 cells Cband	high	126/4698	728.36	-95/+94	180524	0.3							
S. Amer. 4 cells Xband	high	109/4696	735.83	-513/+485	23003764	44.4				-748/+658	9.45	12.44	
S. Amer. 4 cells common voids	high				113299	0.2							
W071S37 Cband	med	855/4698	505.11	-95/+90	30805	0.2	141	6.61	12.35				
W071S37 Xband	med	1073/4696	534.84	-251/+316	4902975	37.8	95	-4.01	14.27	-358/+370	10.97	12.32	
W071S38 Cband	med	733/3973	432.29	-63/+71	3143	0.02	92	4.50	8.72				
W071S38 Xband	med	701/2929	334.75	-209/+256	5959904	46.0	44	-6.57	11.61	-323/+222	10.17	5.29	
W072S37 Cband	high	126/3200	710.34	-86/+94	84779	0.7	314	6.89	15.90				
W072S37 Xband	high	109/3204	716.25	-513/+485	7195827	55.5	175	2.54	25.43	-580/+658	5.95	15.49	
W072S38 Cband	med	221/3532	594.87	-89/+91	61823	0.5	11	11.77	21.52				
W072S38 Xband	high	147/3596	601.33	-382/+459	4951587	38.2	8	3.05	12.77	-748/+404	9.83	13.97	
W07115S3715 Xband													2.57 S.E.
W07130S3715 Xband													2.09 S.E.

Values in meters.

"Difference" statistics generated by subtracting X-band from C-band (C-band - X-band).

"DAT" statistics generated by using C-band as truth and X-band as test.

GCP = Ground Control Point (NGA generated).

DAT = DEM Analysis Tool (GOTS s/w).

NA = Not Available

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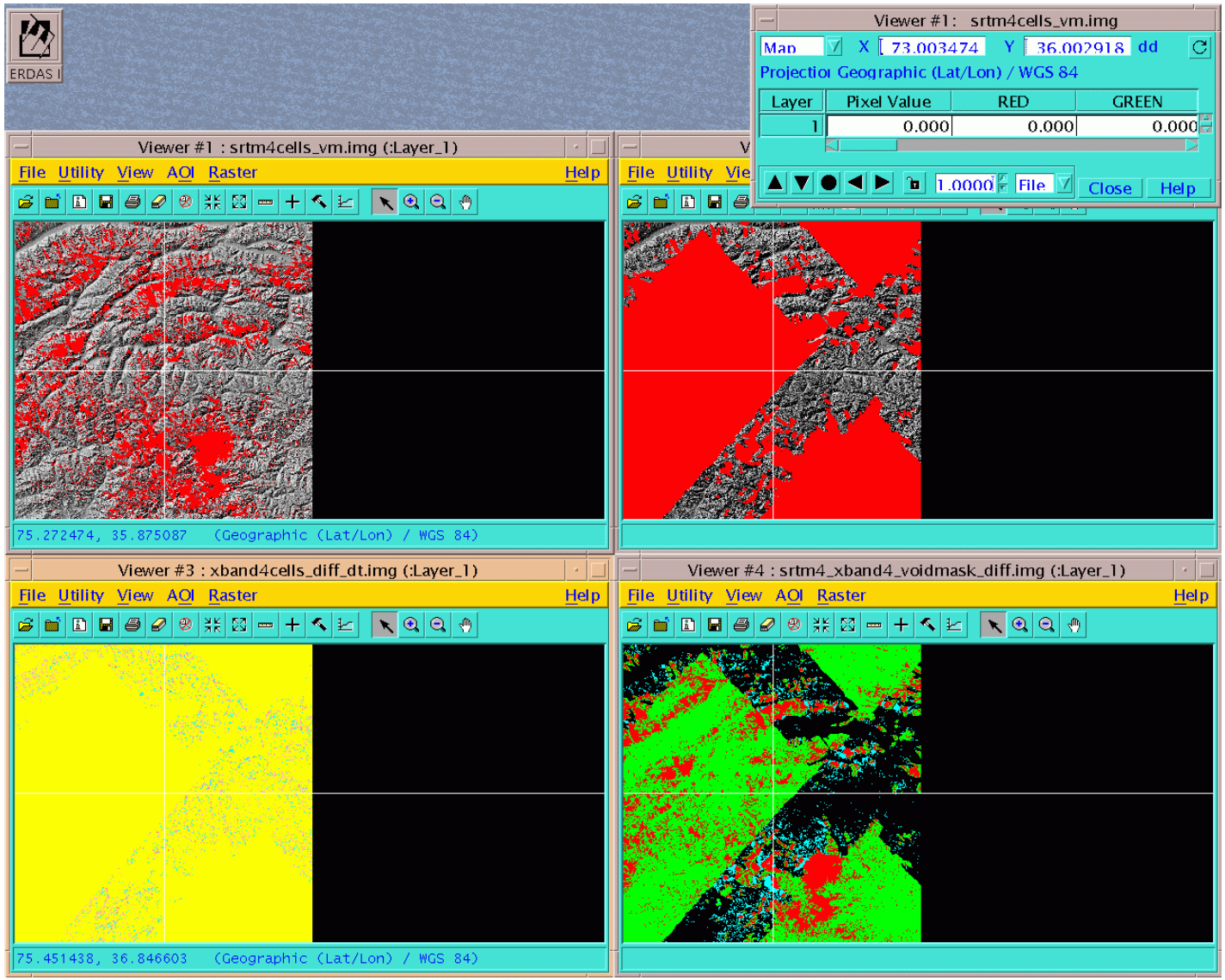
Afghanistan-Pakistan four cells, C-band and X-band data. Overview. C-band upper left, X-band upper right, difference lower left, void masks lower right.



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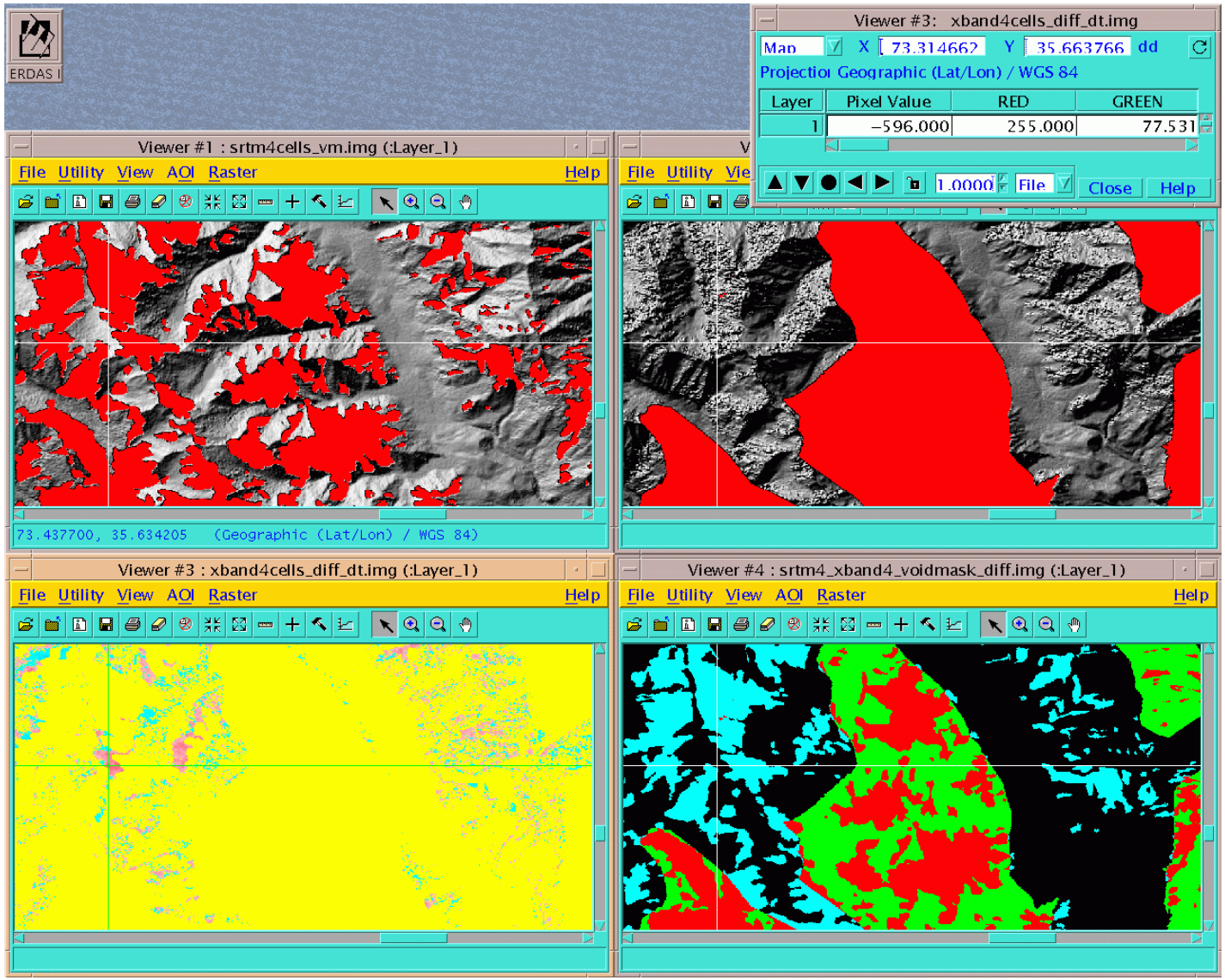
Afghanistan-Pakistan four cells, C-band and X-band data. C-band upper left, X-band upper right, difference lower left, void masks lower right.



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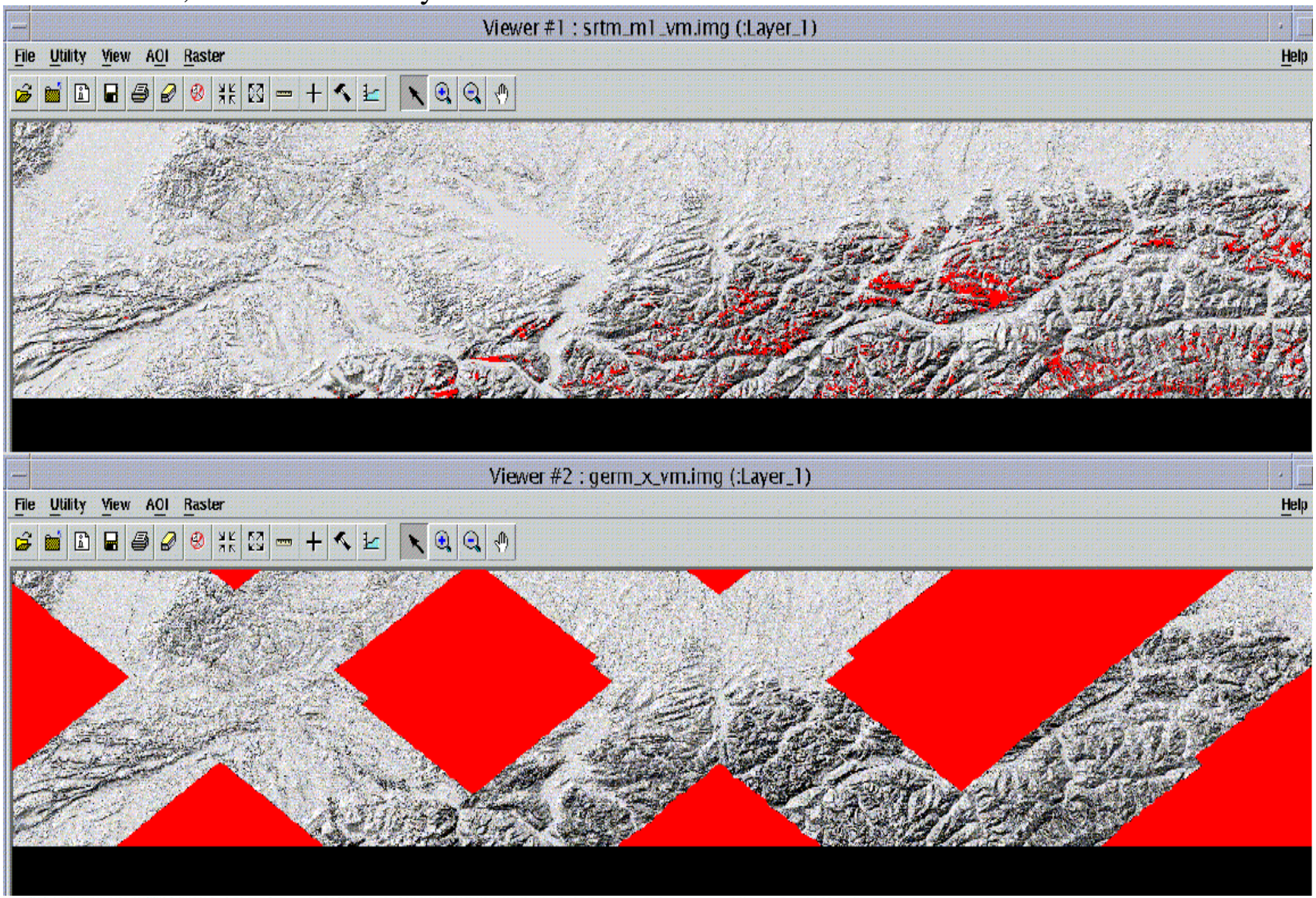
Germany six cells, C-band and X-band data. Overview. Grey scale shade: SRTM top view / X-band bottom view, voids indicated by red.



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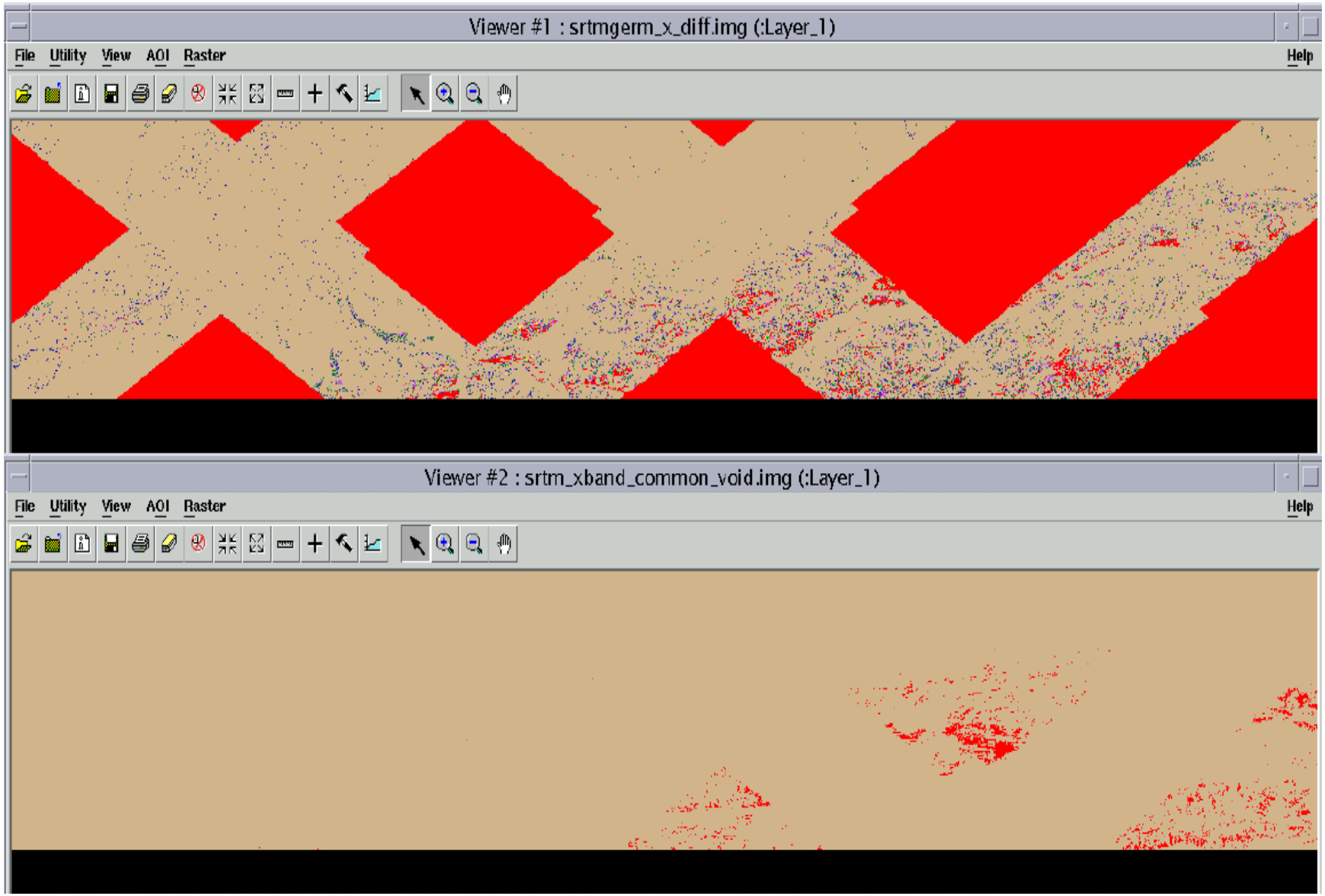
Germany six cells, C-band and X-band data. Overview. Difference file (C-band – X-band) top view, common (remaining) voids bottom view, voids in red.



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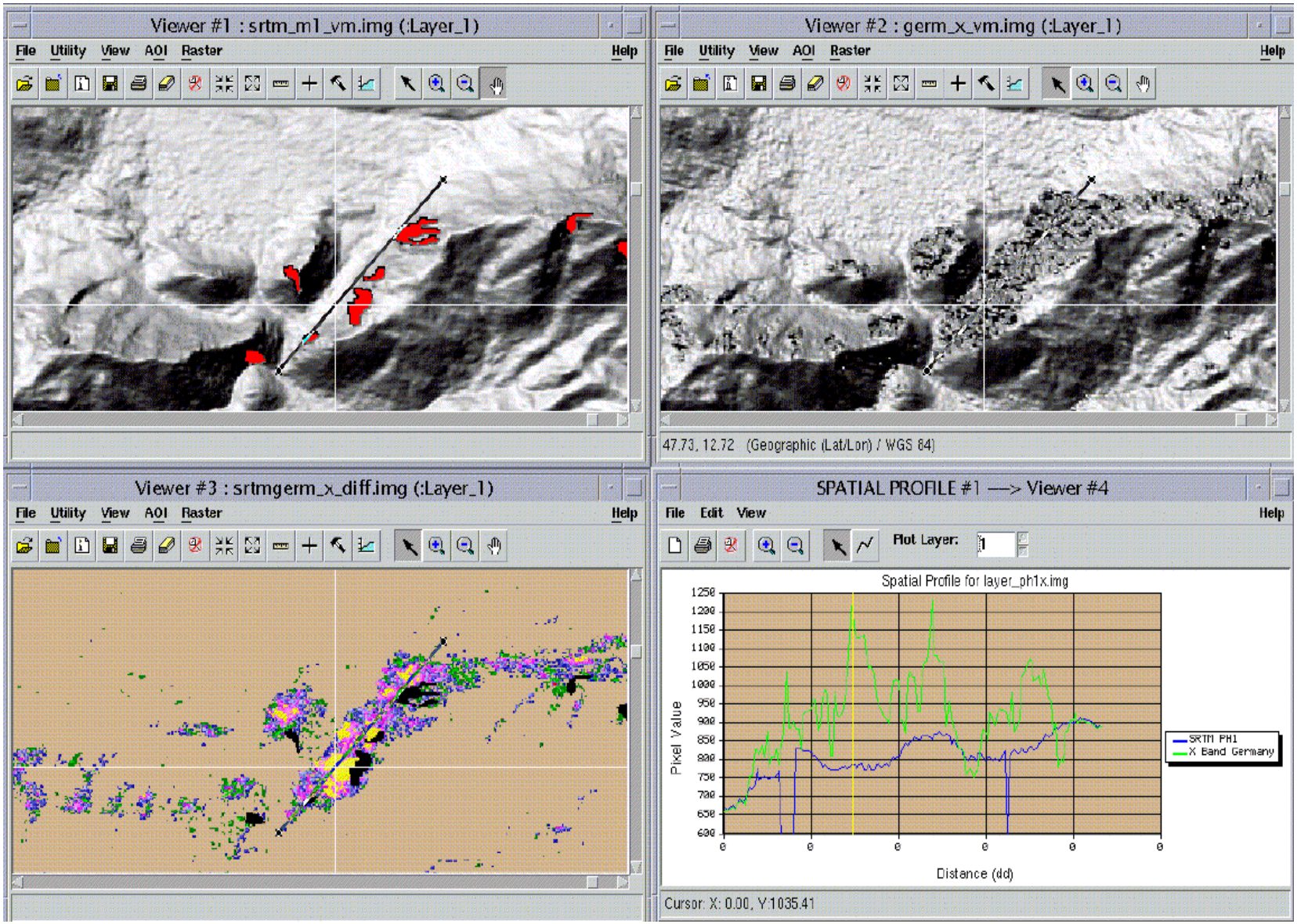
Germany six cells, C-band and X-band data. Example of high noise found in moderate / high relief data in X-band data.



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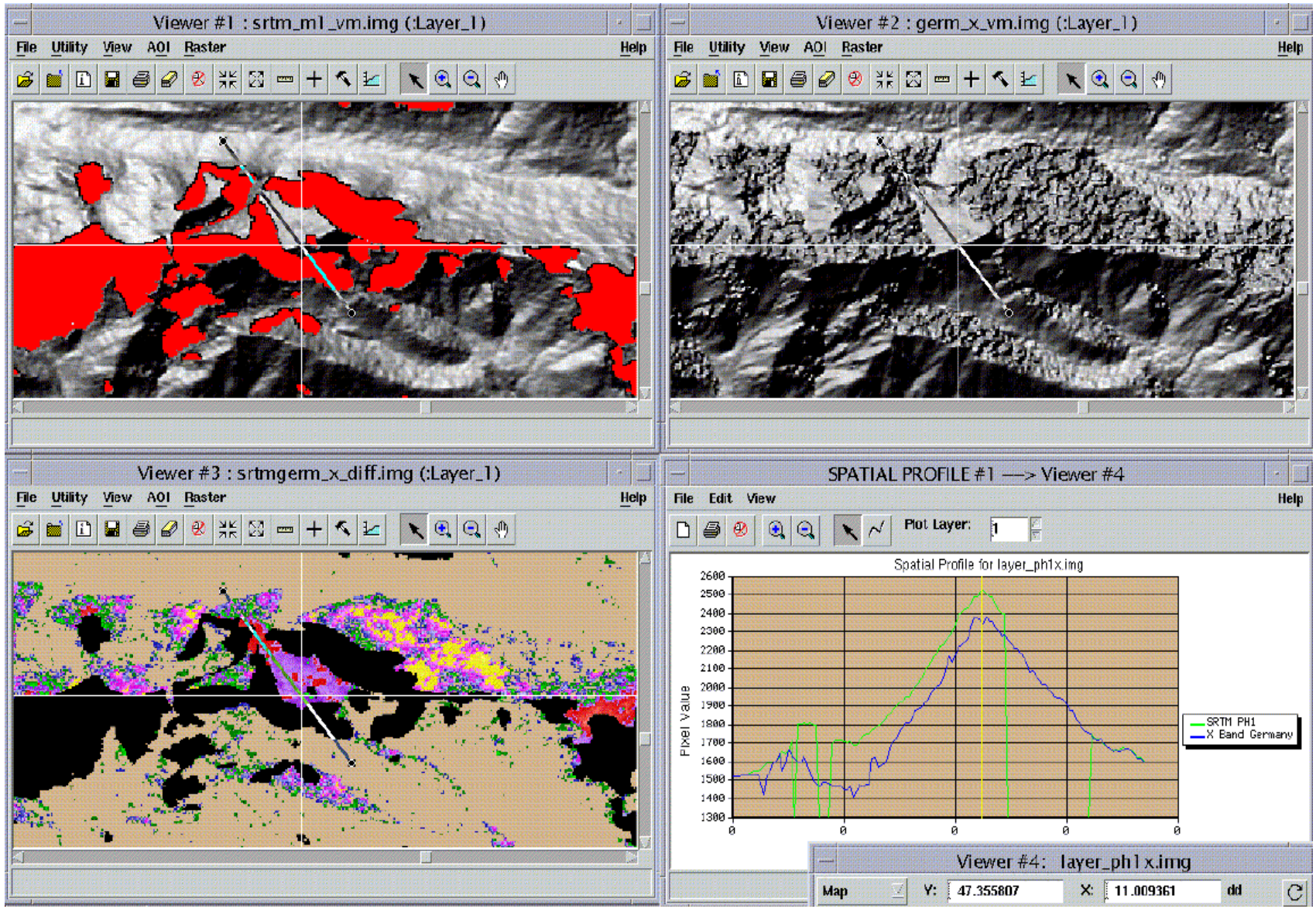
Germany six cells, C-band and X-band data. Example of suspected Phase Unwrap Error in the SRTM data vs. the X-band.



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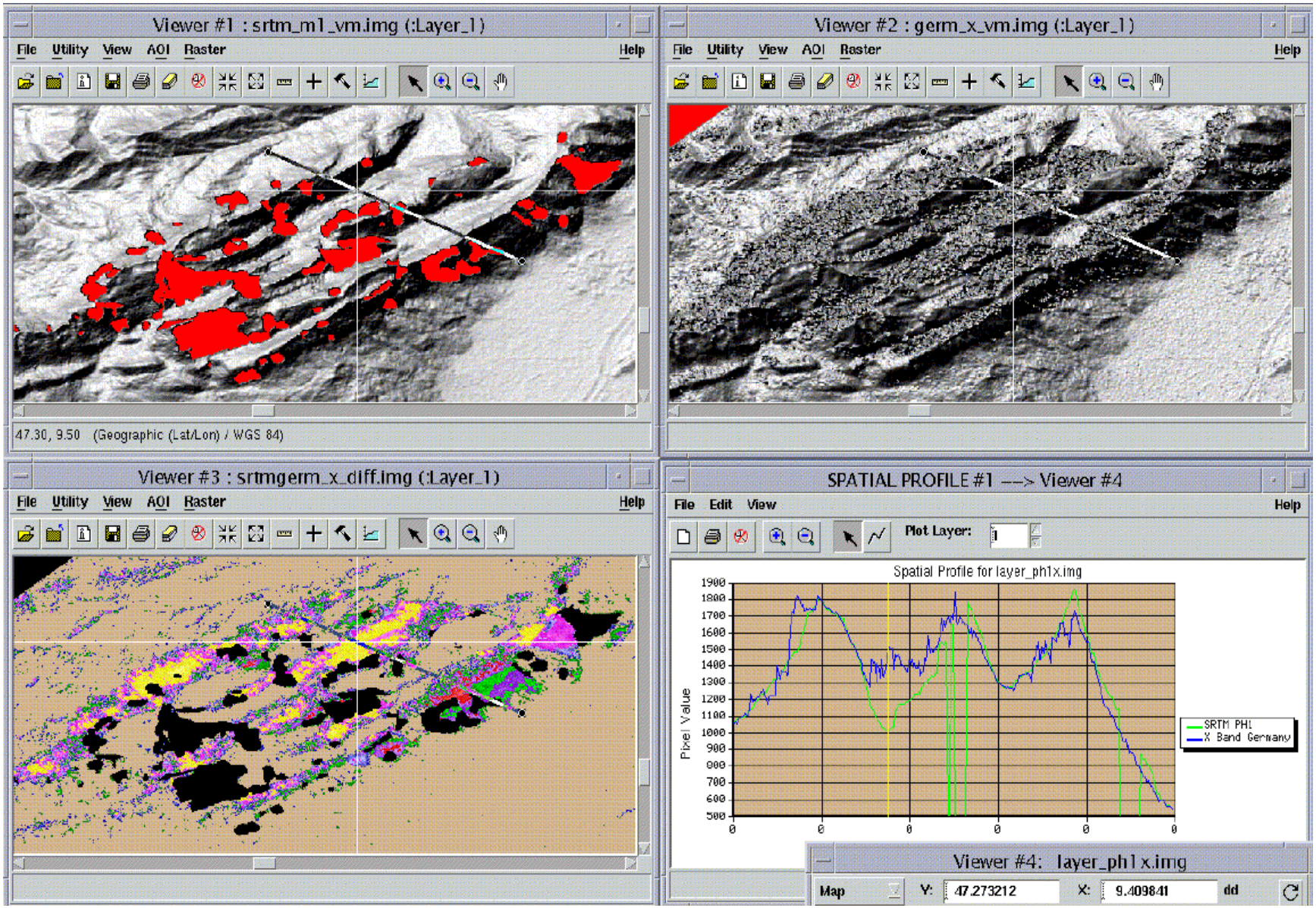
Germany six cells, C-band and X-band data. Example of high noise – larger in viewer / area extend.



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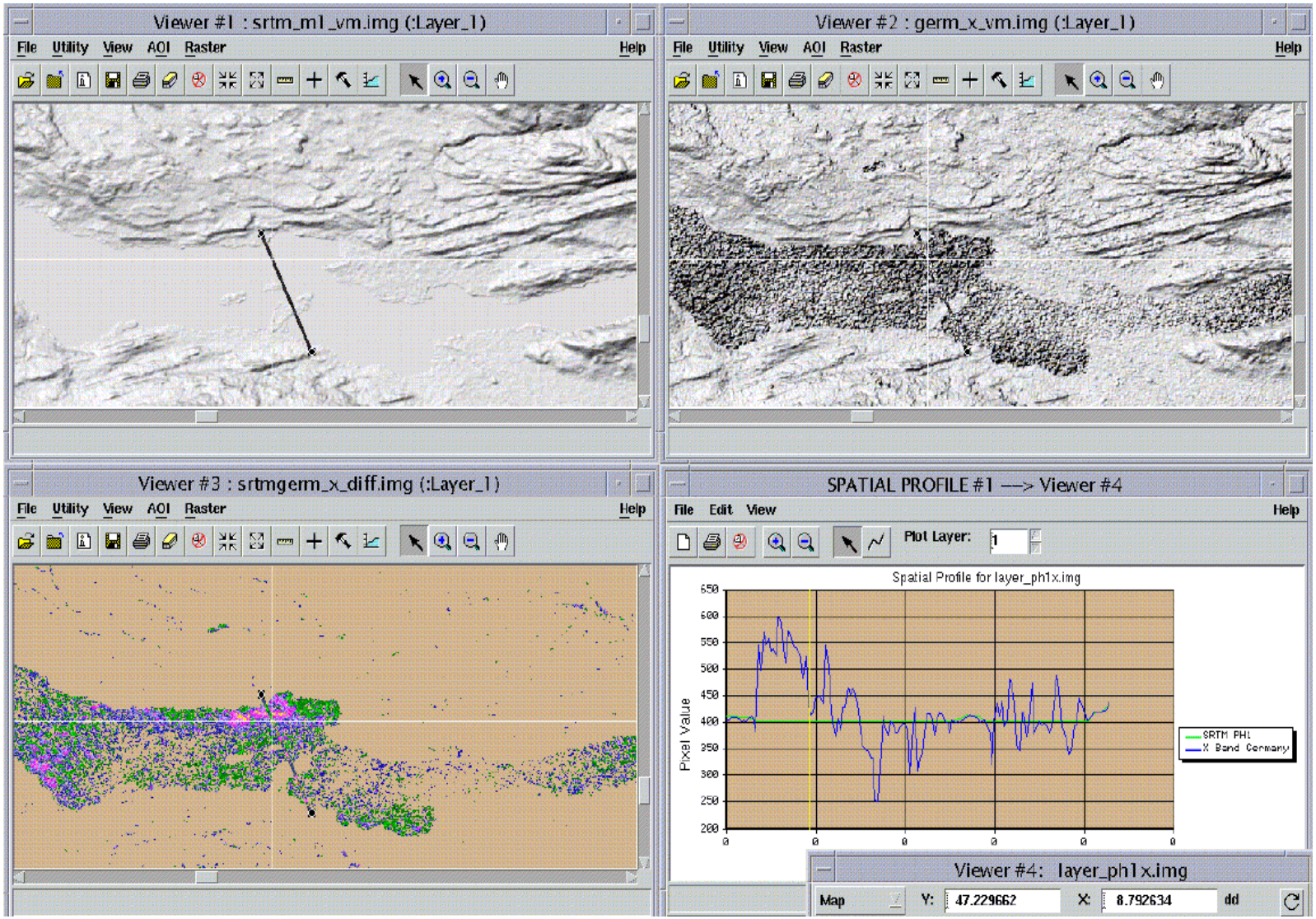
Germany six cells, C-band and X-band data. Example of water (402m) in C-band vs. non water surface indicated in X-band – it should be noted that no voids were identified internal to the X-band data throughout the entire dataset.



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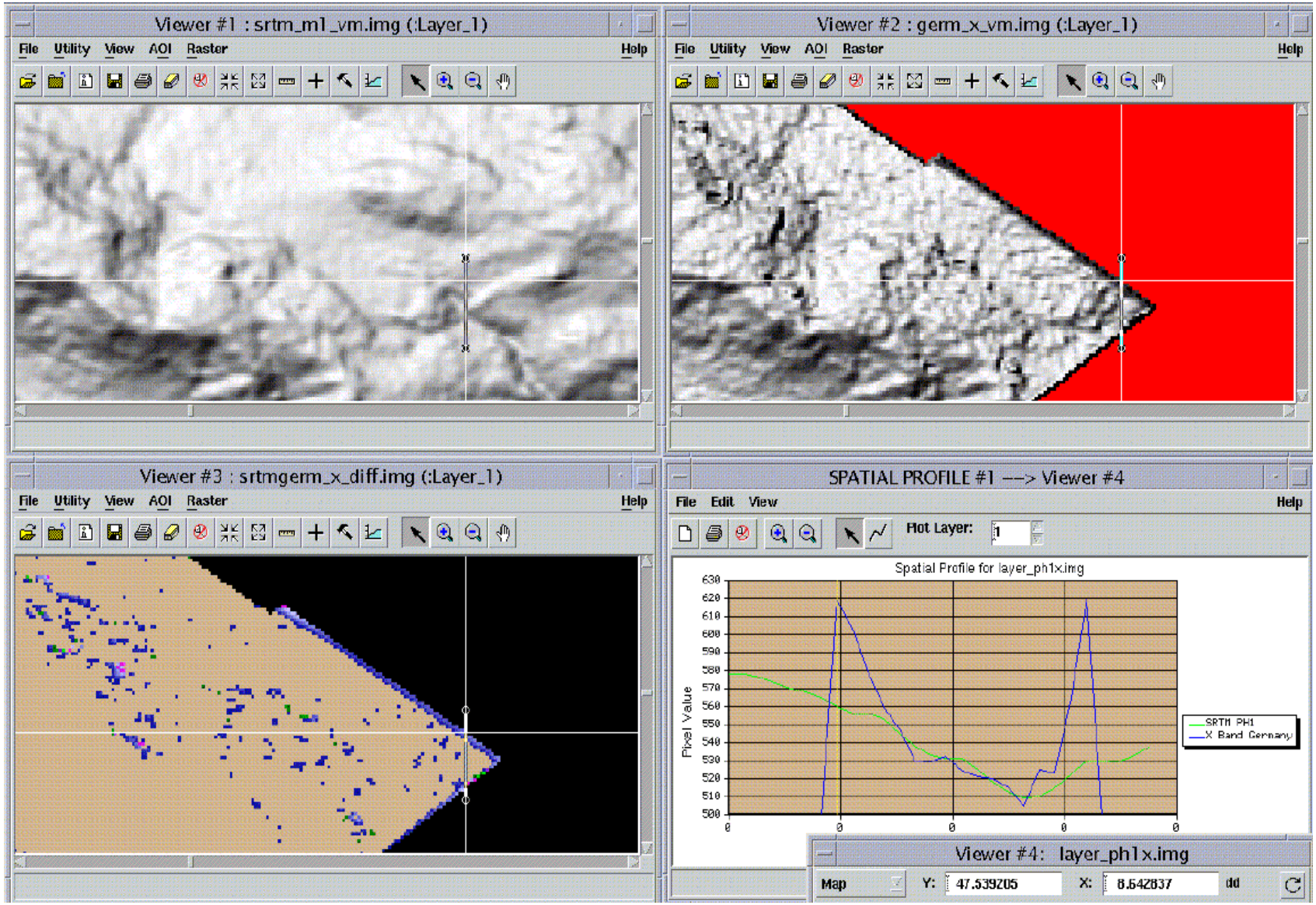
Germany six cells, C-band and X-band data. Example of noise found along X-band seam edges – an artifact found throughout the X-band dataset.



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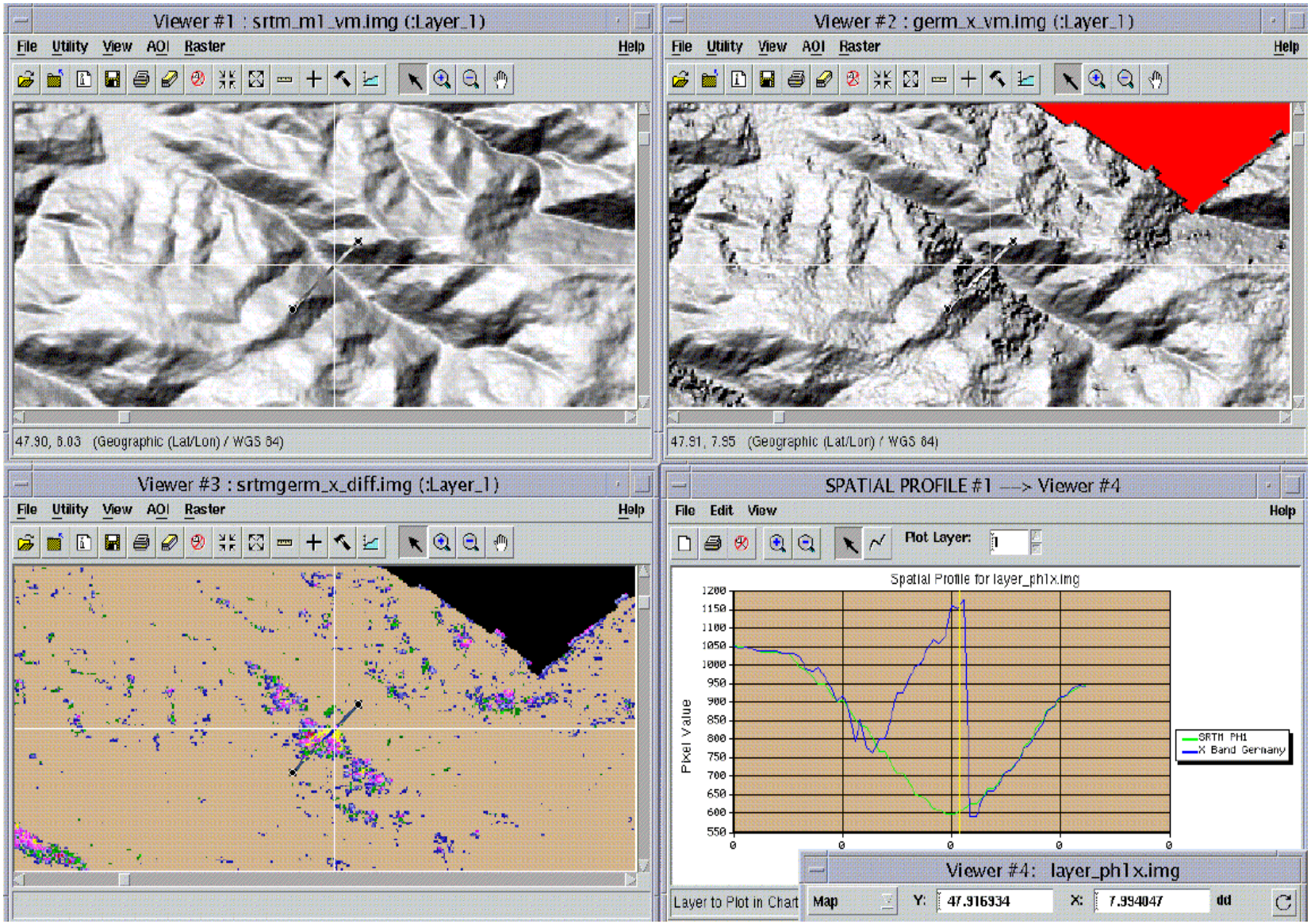
Germany six cells, C-band and X-band data. Example of valley being filled by high noise X-band artifact – note the near 600m vertical offset



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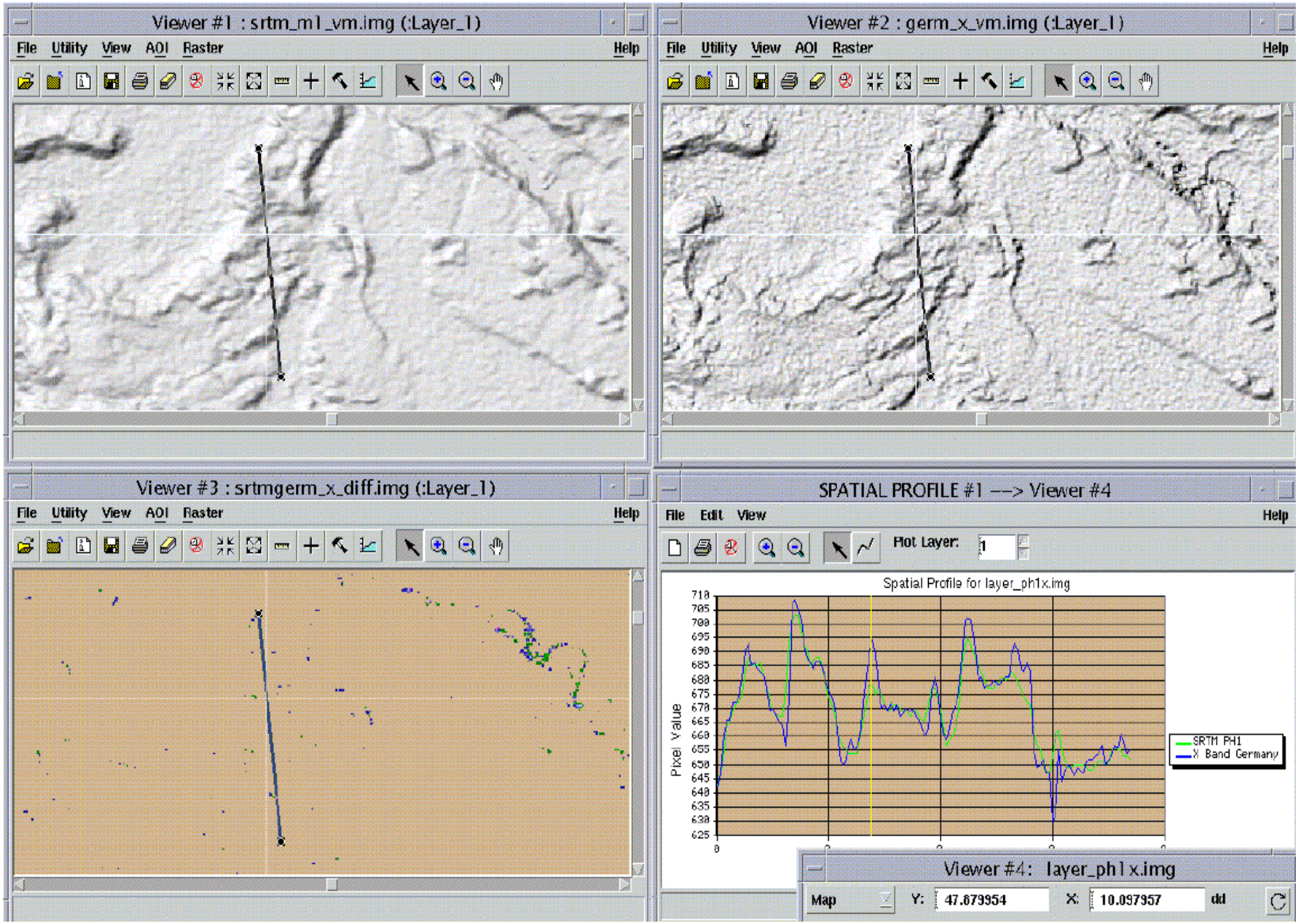
Germany six cells, C-band and X-band data. An isolated case where X-band data appears to have a greater surface depiction – note the better defined ridge/valley depiction in the layer view



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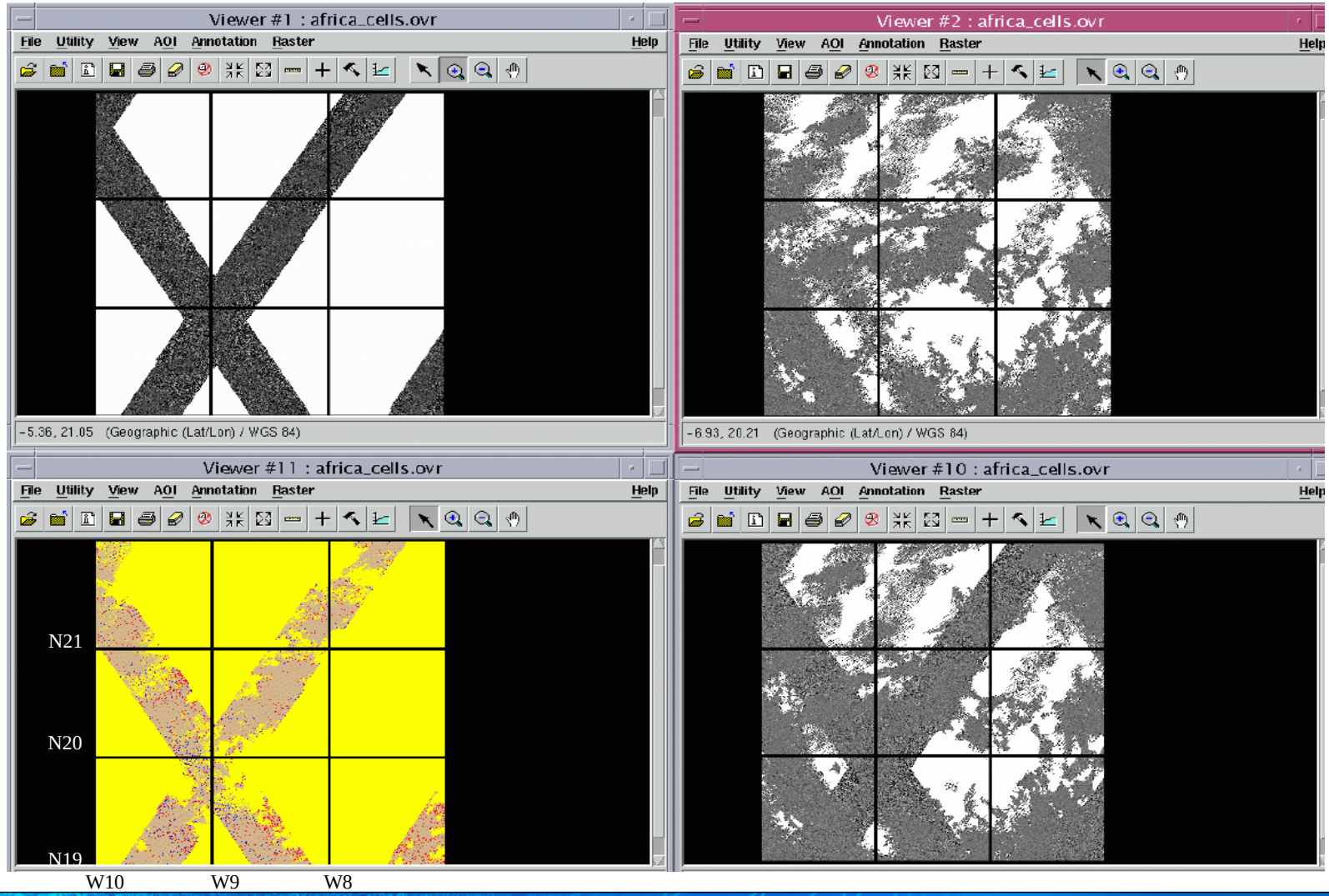
Africa nine cells, C-band and X-band data. Overview. This graphic shows the shaded relief of the X-band in the top left window, the shaded relief of the C-band in the upper right window, the difference file of the C-band minus the X-band in the lower left, and the shaded relief of the merged data in the lower right window.



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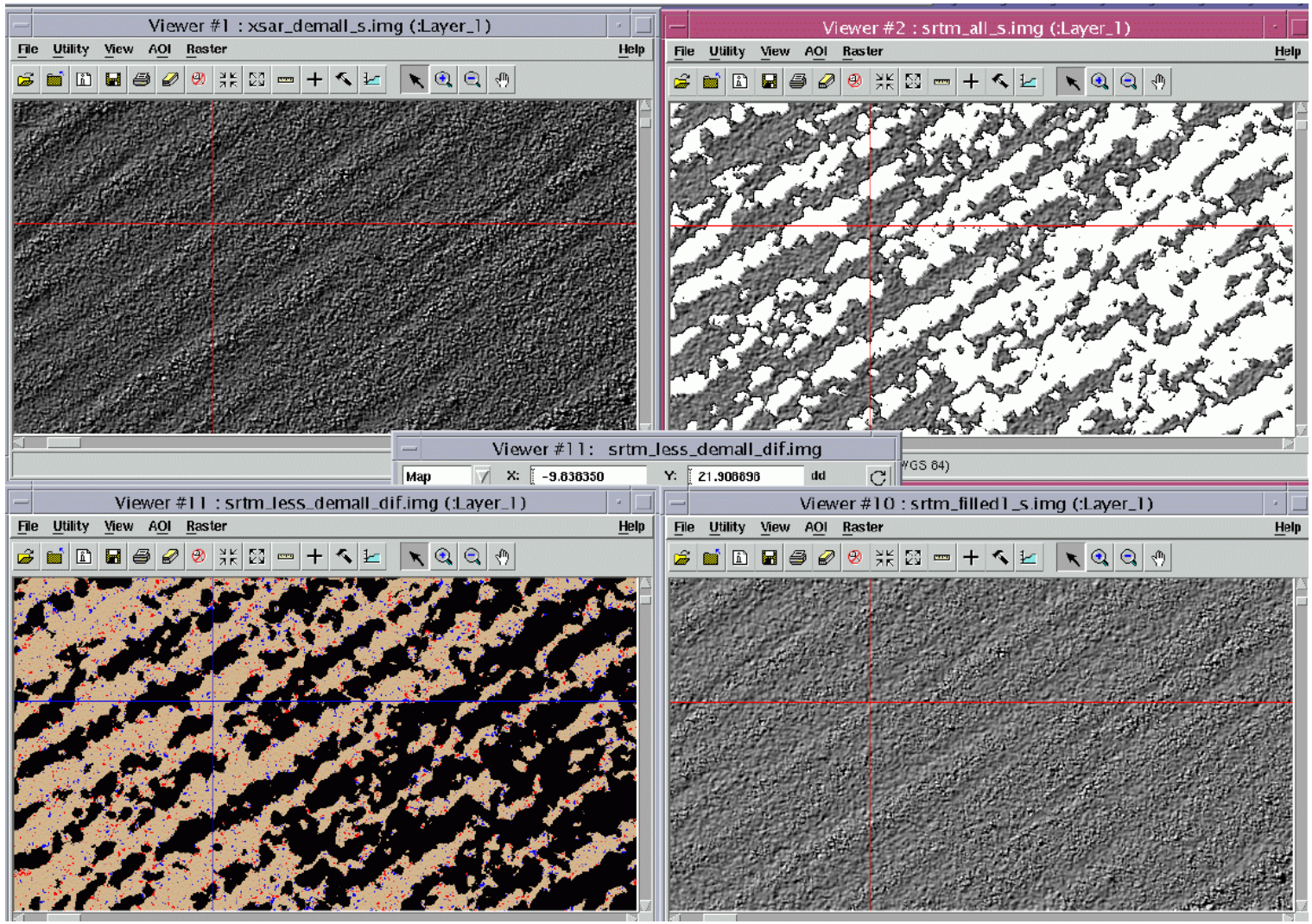
Africa nine cells, C-band and X-band data. The top left shows the shaded relief of the X-band , the top right shows the shaded relief of the C-band, the bottom left shows the difference file with void in black, and the bottom right shows a shaded relief of the C-band filled with X-band data. Notice a little more noise from the fill.



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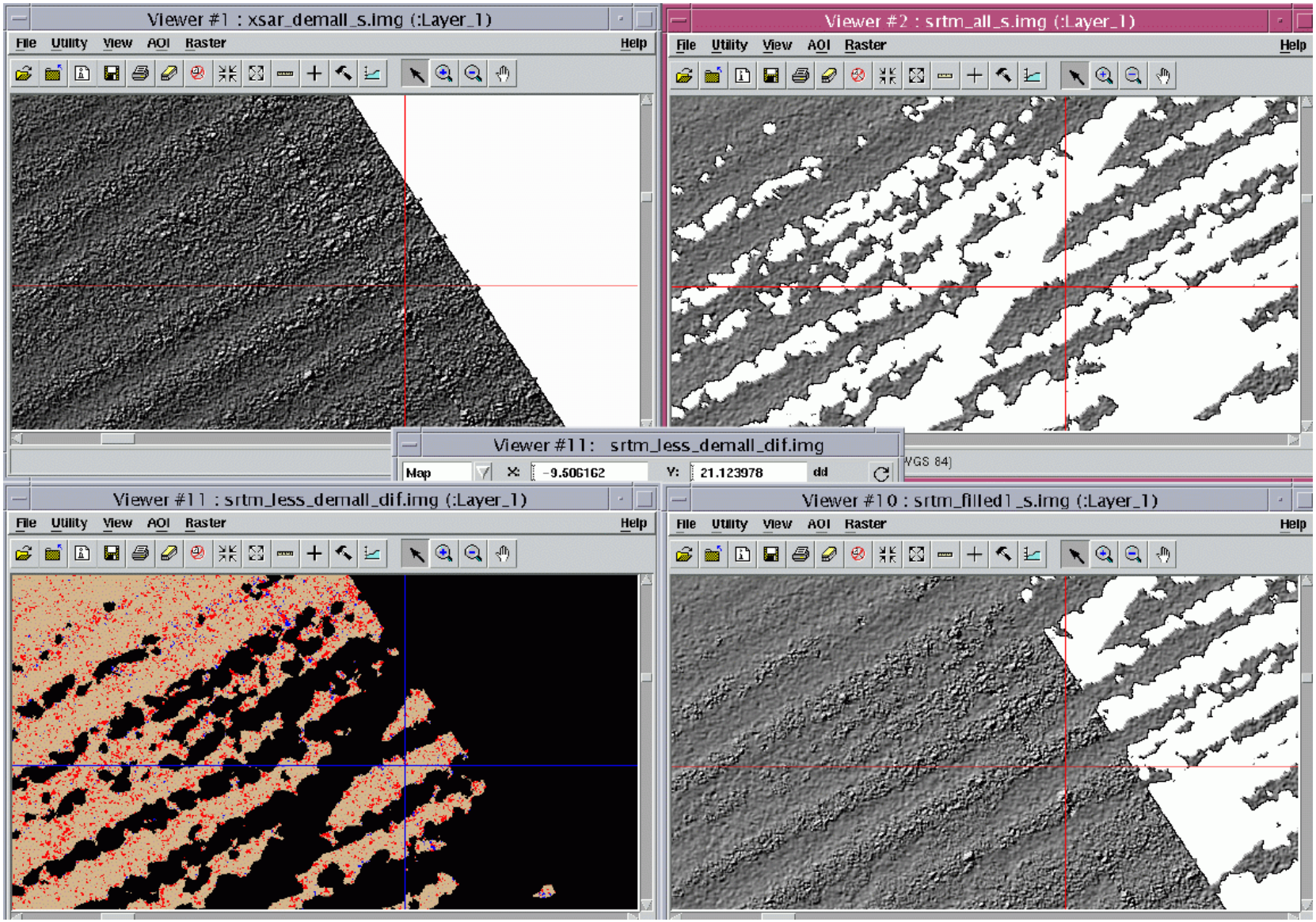
Africa nine cells, C-band and X-band data. Notice the linear pattern in the X-band data near the edge of the void.



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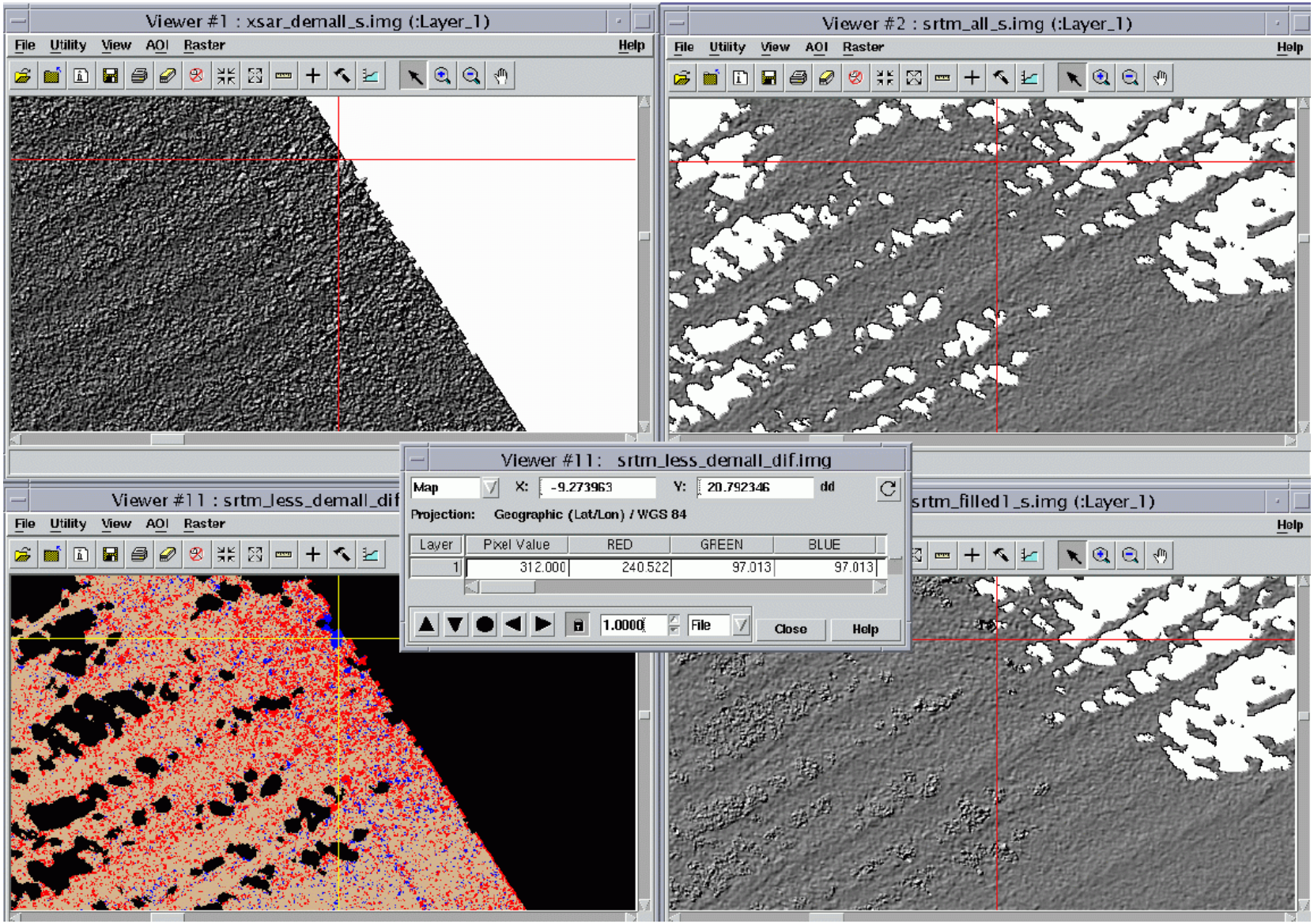
Africa nine cells, C-band and X-band data. The edge of this void shows a large positive delta of 312 meters between the X-band and the C-band.



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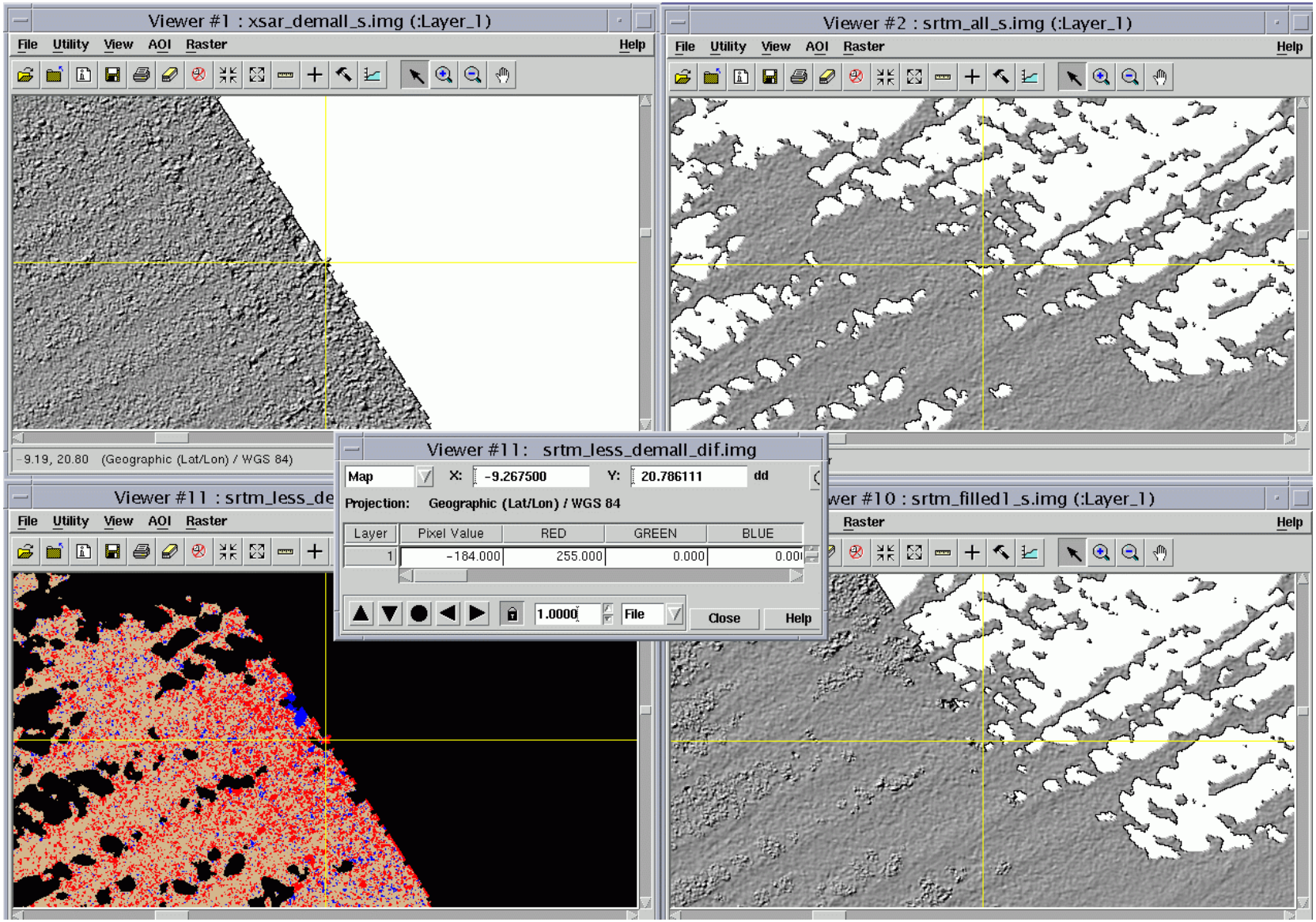
Africa nine cells, C-band and X-band data. This graphic located immediately below the previous graphic shows a large negative difference of –184 meters.



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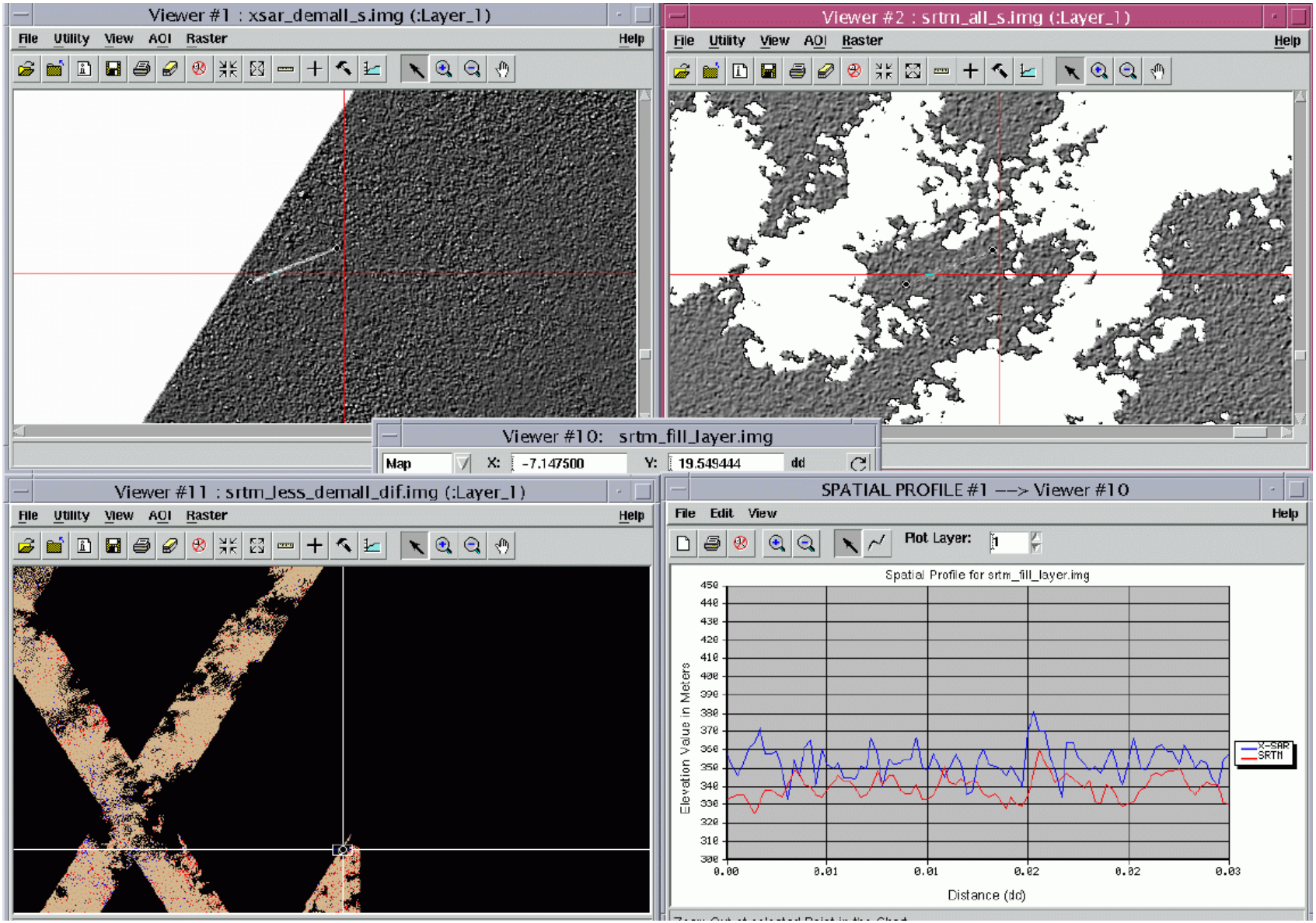
Africa nine cells, C-band and X-band data.



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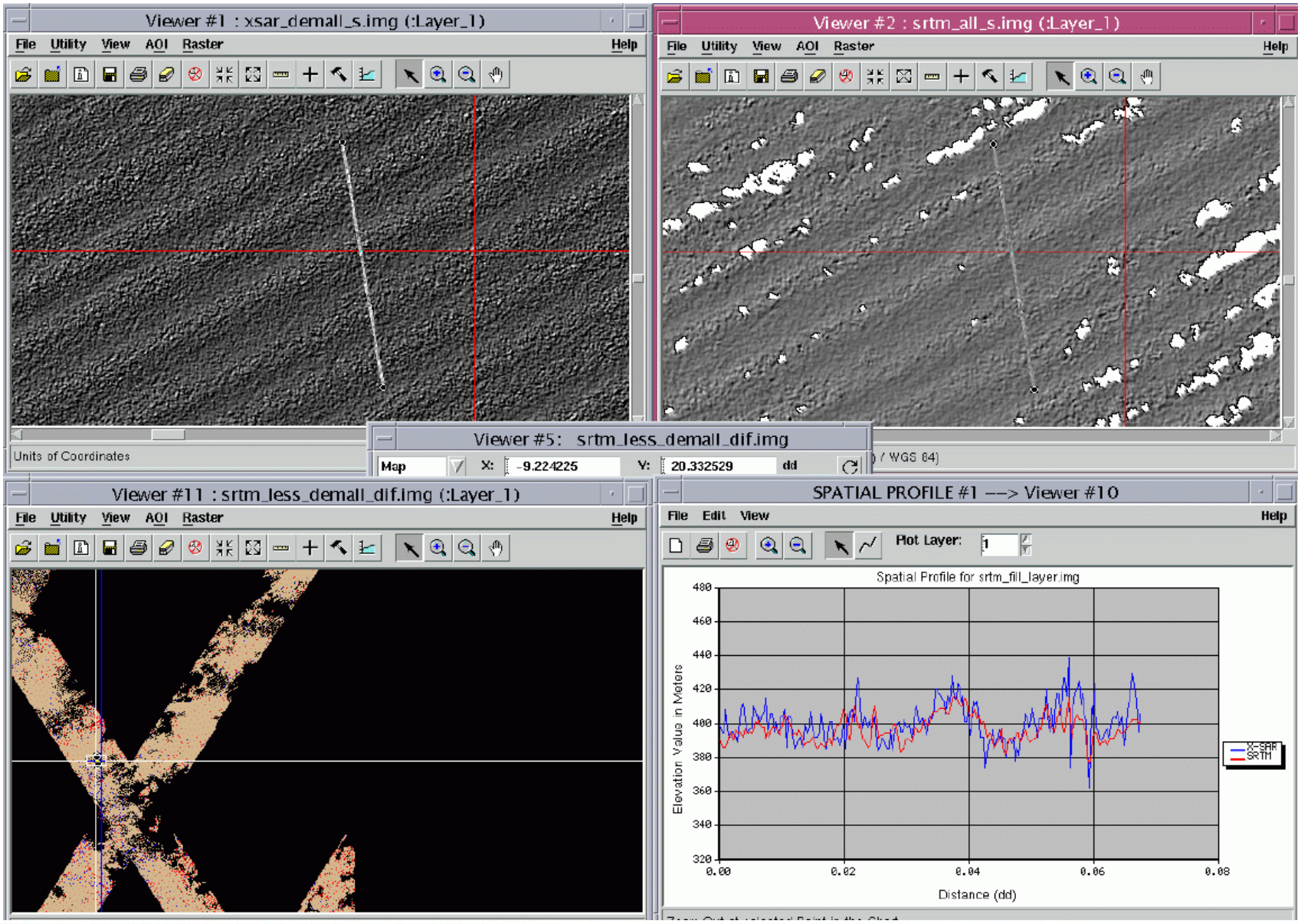
Africa nine cells, C-band and X-band data.



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Results

- X-band data has an excessive amount of void. This is largely due to:
  - The small swath-width of the sensor.
  - Void due to high relief. These voids appear to be hand-cut.
- In areas where C-band data has void and X-band has data, the quality of the X-band data generally exhibits higher than acceptable noise.
- The X-band data exhibits no post-processing water edits. No water bodies were delineated or flattened.
- The X-band data contains isolated cases of completely false landforms whose magnitude may exceed 100 meters and the X band data sometimes contains large anomalies at the edge of the swath/seam.

Conclusions

- The X-band data, coincident with C-band voids, was found to be of generally unacceptable quality.
- The amount of void found in the X-band data is extremely problematic. The 23 cells of X-band data averaged 54.5% void /cell.
- We assume the X-band data used in this evaluation are indicative of the overall quality of all of the X-band data.
- Based on the results of this evaluation the utility of X-band data for use as C-band void fill appears to be very limited.
- Our recommendation is to **NOT** pursue use of X-band data for C-band void fill.

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