C.5 Study site HVG1 (tussock sedge, dwarf shrub, moss tundra)

I *Location*

Name	Location	Latitude	Longitude	Altitude
HVG1	Happy Valley, Arctic North Slope, Alaska, United States of America	69.146897°	-148.85183°	325 m

Happy Valley is located just west of the Dalton Highway in the foothills of the Arctic Slope approximately 82 km (52 mi) north of Toolik Lake, Alaska at an elevation of about 320 m. Within the five subzones of the circumpolar Arctic, Happy Valley is found in subzone E. Green mile marker 334 is positioned just before the turn-off to the site. Three 10 x 10 m grids, designated at the hill crest, midslope and at the footslope have been established at this location in 2002. The goniometer measurements have been carried out next to the midslope / zonal site (HV_ms/z). [*Barreda et al.*, 2006]

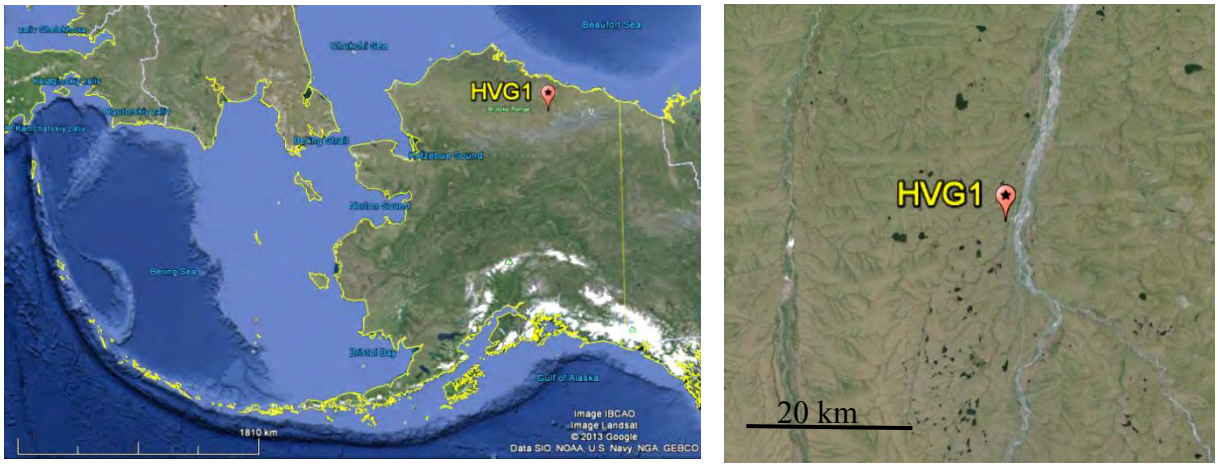

Figure C.5-1: Location of study site HVG1 in Alaska, USA. *Source:* Google Earth, 2013

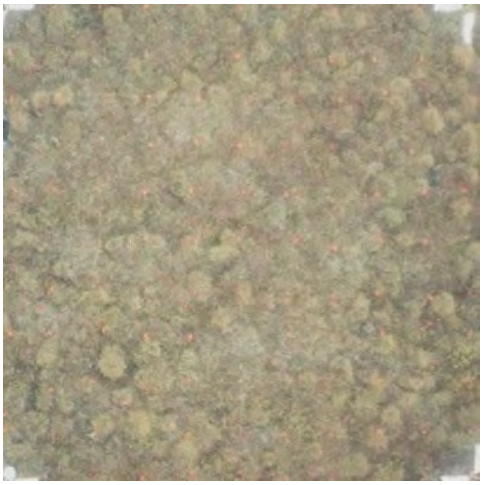

Figure C.5-2: Aerial photo of a 10x10 m zonal grid at the Happy Valley study location near the HVG1 site. *Source:* [*Barreda et al.*, 2006]

II *Main Vegetation Description*

The vegetation at the mesic Happy Valley study location corresponds to the zonal vegetation in subzone E. The zonal plant community of bioclimate subzone E in northern Alaska is *Sphagno- Eriophoretum vaginati* [*Walker et al.*, 1994], also called moist acidic tundra (MAT), 'acidic tussock tundra' or 'tussock-sedge, dwarf-shrub, moss tundra' [*Walker et al.*, 2005]. It occurs widely across the foothills of northern Alaska on old upland surfaces not glaciated during the Last Glacial Maximum. At Happy Valley the average soil pH of this plant community is 5.3; the average volumetric soil moisture of the top mineral horizon is 44 %, and average depth of thaw by late summer is 34 cm [*Kade et al.*, 2005]. The vegetation is composed of a mixture of tussock sedges (*Eriophorum vaginatum*), deciduous dwarf shrubs (e.g., *Betula nana, Salix planifolia* ssp. *pulchra*), evergreen dwarf shrubs (e.g., *Ledum palustre* ssp. *decumbens, Vaccinium vitis-idaea, Cassiope tetragona, Empetrum nigrum*), a few forbs (*Polygonum bistorta* var. *plumosum, Petasites frigidus*), mosses (*Hylocomium splendens, Sphagnum* spp., *Aulacomnium* spp., *Dicranum* spp.) and lichens (*Cladina* spp., *Dactylina arctica*, *Cetraria* spp.).

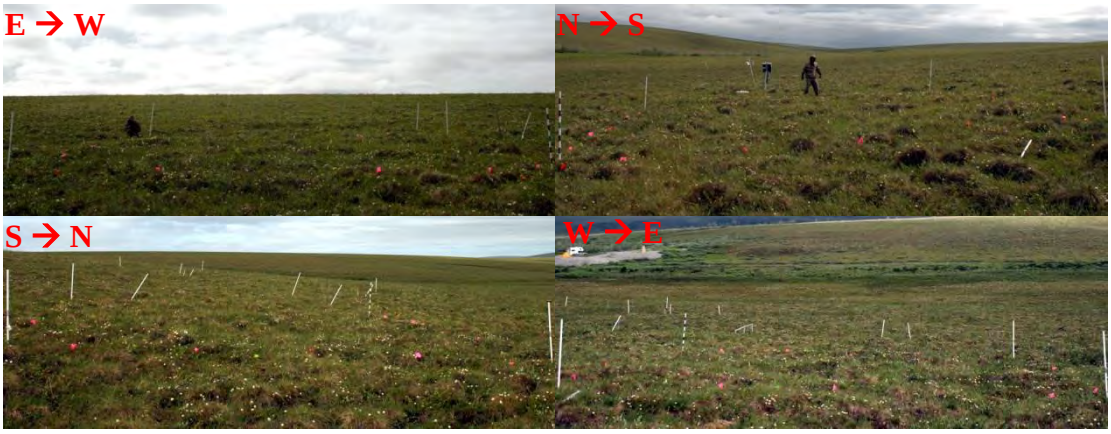

Figure C.5-3: Overview images of MNT tundra at the mesic Happy Valley study location near the HVG1 site. *Source:* [*Buchhorn and Schwieder*, 2012]

III *Vegetation Description of the HVG1 Site*

The focus of the measurements at this goniometer site has been tussock sedge – dwarf shrub – moss tundra. The 1 x 1 m plot is homogeneously covered with this tussock structure, but with forbs, mosses and lichens in the understory. Moreover, this plot correspond with the zonal plant community of Alaskan bioclimate subzone E (MAT vegetation).

Figure C.5-4: Overview images of the HVG1 vegetation from cardinal directions.

Figure C.5-5: Quasi-nadir image of the HVG1 vegetation (tussock sedge).

IV *Overview of the Spectro-Goniometer Measurements*

Table C.5-1: Overview of the spectro-goniometer measurements at the HVG1 study site.

Name	Day	Starting Time	Duration	SAA	SZA	Sky
HVG1_01	2012-06-30	10:17:57	24 min	118°	56°	cirrostratus
HVG1_02	2012-06-30	11:35:48	21 min	139°	50°	clear
HVG1_03	2012-06-30	13:47:45	20 min	179°	46°	clear

Table C.5-2: Spectro-directional data of the HVG1_01 spectro-goniometer measurement.

HVG1_01 (SZA = 56°; SAA = 118°)	Viewing Geometry (Viewing Zenith Angle | Viewing Azimuth Angle)																							
	0|0	5|180	5|202.5	5|225	5|270	5|315	5|337.5	5|0	5|22.5	5|45	5|90	5|135	5|157.5	10|180	10|202.5	10|225	10|270	10|315	10|337.5	10|350
HCRF EnMAP blue (479 nm)	0.0364	0.0362	0.0351	0.0337	0.0468	0.0461	0.0510	0.0365	0.0416	0.0448	0.0398	0.0401	0.0380	0.0360	0.0352	0.0343	0.0430	0.0577	0.0555	0.0393
HCRF EnMAP green (549 nm)	0.0695	0.0714	0.0613	0.0621	0.0827	0.0689	0.0792	0.0578	0.0638	0.0736	0.0711	0.0812	0.0731	0.0734	0.0689	0.0681	0.0803	0.0831	0.0865	0.0620
HCRF EnMAP rot (672 nm)	0.0667	0.0615	0.0577	0.0562	0.0748	0.0756	0.0880	0.0613	0.0722	0.0781	0.0759	0.0739	0.0671	0.0636	0.0607	0.0589	0.0702	0.0924	0.0893	0.0624
HCRF EnMAP NIR (864 nm)	0.3139	0.3101	0.2435	0.2842	0.3690	0.2617	0.2883	0.2237	0.2359	0.2731	0.3098	0.3731	0.3117	0.3243	0.3260	0.2991	0.3290	0.3676	0.2756	0.3004	0.2314
ANIF EnMAP rot (672 nm)	1.0000	0.9225	0.8656	0.8437	1.1226	1.1344	1.3201	0.9196	1.0831	1.1710	1.1391	1.1091	1.0071	0.9545	0.9553	0.9108	0.8838	1.0534	1.3860	1.3397	0.9364
ANIF EnMAP NIR (864 nm)	1.0000	0.9877	0.7756	0.9052	1.1755	0.8335	0.9183	0.7126	0.7513	0.8700	0.9869	1.1884	0.9929	1.0329	1.0384	0.9527	1.0481	1.1710	0.8780	0.9568	0.7371
Rel. Blue Absorption Depth	0.5068	0.5391	0.4513	0.5074	0.4965	0.3607	0.3714	0.3720	0.3498	0.4014	0.4595	0.5597	0.5234	0.5683	0.5587	0.5306	0.5597	0.5264	0.3419	0.3749	0.3736
Rel. Red Absorption Depth	1.4401	1.5558	1.2292	1.5189	1.4475	0.8878	0.8475	0.9621	0.8665	0.9516	1.1934	1.5799	1.4140	1.5782	1.5877	1.4982	1.7314	1.5643	0.7270	0.8899	1.0080
NDVI (EnMAP)	0.6497	0.6690	0.6168	0.6695	0.6628	0.5516	0.5322	0.5698	0.5312	0.5554	0.6063	0.6692	0.6455	0.6719	0.6731	0.6624	0.6962	0.6792	0.4978	0.5416	0.5750
Nadir Norm. NDVI (AVHRR)	1.0000	1.0183	0.9397	1.0220	0.9996	0.8529	0.8263	0.8719	0.8264	0.8575	0.9441	1.0237	0.9854	1.0219	1.0165	1.0030	1.0599	1.0252	0.7669	0.8324	0.8837
Nadir Norm. NDVI (MODIS)	1.0000	1.0228	0.9429	1.0224	1.0002	0.8499	0.8234	0.8696	0.8229	0.8549	0.9431	1.0255	0.9864	1.0236	1.0192	1.0048	1.0618	1.0257	0.7646	0.8318	0.8830
Nadir Norm. NDVI (EnMAP)	1.0000	1.0297	0.9494	1.0306	1.0202	0.8490	0.8192	0.8770	0.8176	0.8549	0.9332	1.0301	0.9937	1.0342	1.0361	1.0197	1.0717	1.0454	0.7663	0.8336	0.8852

(cont.)

HVG1_01 (SZA = 56°; SAA = 118°)	Viewing Geometry (Viewing Zenith Angle | Viewing Azimuth Angle)																							
	10|0	10|10	10|22.5	10|45	10|90	10|135	10|157.5	10|170	20|180	20|190	20|202.5	20|225	20|270	20|315	20|337.5	20|350	20|0	20|10	20|22.5	20|45	20|90
HCRF EnMAP blue (479 nm)	0.0362	0.0375	0.0405	0.0441	0.0418	0.0403	0.0415	0.0383	0.0461	0.0436	0.0412	0.0453	0.0382	0.0510	0.0380	0.0396	0.0351	0.0378	0.0415	0.0430	0.0384
HCRF EnMAP green (549 nm)	0.0561	0.0587	0.0633	0.0709	0.0706	0.0772	0.0787	0.0758	0.0882	0.0844	0.0814	0.0922	0.0802	0.0809	0.0605	0.0582	0.0528	0.0577	0.0648	0.0707	0.0646
HCRF EnMAP rot (672 nm)	0.0582	0.0624	0.0710	0.0766	0.0767	0.0722	0.0724	0.0677	0.0855	0.0782	0.0742	0.0802	0.0679	0.0866	0.0613	0.0639	0.0561	0.0625	0.0706	0.0746	0.0703
HCRF EnMAP NIR (864 nm)	0.2121	0.2238	0.2432	0.2688	0.2817	0.3413	0.3200	0.3249	0.3460	0.3375	0.3482	0.4091	0.3774	0.3022	0.2302	0.2109	0.2039	0.2220	0.2520	0.2751	0.2610
ANIF EnMAP rot (672 nm)	0.8731	0.9365	1.0651	1.1494	1.1504	1.0822	1.0854	1.0155	1.2819	1.1730	1.1135	1.2025	1.0183	1.2995	0.9188	0.9581	0.8409	0.9375	1.0590	1.1196	1.0546
ANIF EnMAP NIR (864 nm)	0.6756	0.7128	0.7748	0.8563	0.8974	1.0870	1.0193	1.0349	1.1020	1.0751	1.1091	1.3032	1.2020	0.9625	0.7333	0.6719	0.6494	0.7071	0.8027	0.8764	0.8315
Rel. Blue Absorption Depth	0.3541	0.3531	0.3684	0.3846	0.4180	0.5158	0.5176	0.5505	0.5101	0.5341	0.5490	0.5840	0.5998	0.3932	0.3849	0.3213	0.3346	0.3487	0.3650	0.3952	0.4089
Rel. Red Absorption Depth	0.9821	0.9727	0.9385	0.9685	1.0518	1.4516	1.3300	1.4701	1.1871	1.2999	1.4223	1.5838	1.6988	0.9287	1.0059	0.8844	0.9708	0.9631	0.9829	1.0533	1.0734
NDVI (EnMAP)	0.5693	0.5637	0.5481	0.5564	0.5720	0.6510	0.6312	0.6551	0.6038	0.6237	0.6485	0.6723	0.6950	0.5543	0.5797	0.5351	0.5686	0.5606	0.5623	0.5732	0.5756
Nadir Norm. NDVI (AVHRR)	0.8741	0.8688	0.8481	0.8606	0.8960	0.9980	0.9631	1.0008	0.9163	0.9443	0.9888	1.0170	1.0528	0.8503	0.8898	0.8362	0.8773	0.8657	0.8653	0.8840	0.8955
Nadir Norm. NDVI (MODIS)	0.8731	0.8670	0.8447	0.8591	0.8942	0.9993	0.9648	1.0025	0.9176	0.9469	0.9898	1.0194	1.0534	0.8478	0.8886	0.8338	0.8750	0.8642	0.8636	0.8842	0.8941
Nadir Norm. NDVI (EnMAP)	0.8763	0.8677	0.8436	0.8564	0.8805	1.0020	0.9715	1.0084	0.9294	0.9601	0.9982	1.0349	1.0698	0.8532	0.8923	0.8237	0.8753	0.8629	0.8655	0.8823	0.8860

(cont.)

HVG1_01 (SZA = 56°; SAA = 118°)	Viewing Geometry (Viewing Zenith Angle | Viewing Azimuth Angle)																							
	20|135	20|157.5	20|170	30|180	30|190	30|202.5	30|225	30|270	30|315	30|337.5	30|350	30|0	30|10	30|22.5	30|45	30|90	30|135	30|157.5	30|170			
HCRF EnMAP blue (479 nm)	0.0330	0.0404	0.0434	0.0574	0.0519	0.0436	0.0420	0.0365	0.0473	0.0425	0.0318	0.0337	0.0381	0.0430	0.0455	0.0402	0.0450	0.0521	0.0547					
HCRF EnMAP green (549 nm)	0.0663	0.0809	0.0882	0.1184	0.0998	0.0882	0.0919	0.0663	0.0778	0.0629	0.0492	0.0503	0.0557	0.0628	0.0675	0.0663	0.0858	0.1039	0.1109					
HCRF EnMAP rot (672 nm)	0.0591	0.0739	0.0796	0.1099	0.0977	0.0782	0.0759	0.0632	0.0787	0.0679	0.0525	0.0552	0.0610	0.0686	0.0753	0.0732	0.0825	0.1007	0.1062					
HCRF EnMAP NIR (864 nm)	0.3018	0.3415	0.3636	0.4776	0.3804	0.3554	0.4209	0.3094	0.2937	0.2161	0.2024	0.2004	0.2086	0.2244	0.2408	0.2640	0.3487	0.4224	0.4382					
ANIF EnMAP rot (672 nm)	0.8865	1.1083	1.1931	1.6488	1.4648	1.1725	1.1381	0.9478	1.1806	1.0183	0.7880	0.8285	0.9150	1.0286	1.1287	1.0984	1.2369	1.5099	1.5922					
ANIF EnMAP NIR (864 nm)	0.9613	1.0879	1.1581	1.5214	1.2116	1.1321	1.3408	0.9857	0.9356	0.6885	0.6446	0.6384	0.6644	0.7149	0.7671	0.8410	1.1109	1.3453	1.3959					
Rel. Blue Absorption Depth	0.5443	0.5481	0.5650	0.5794	0.5281	0.5706	0.6428	0.4878	0.4109	0.3152	0.3452	0.3307	0.3143	0.3197	0.3237	0.3919	0.5076	0.5551	0.5640					
Rel. Red Absorption Depth	1.5658	1.4174	1.3929	1.3217	1.1557	1.3519	1.7272	1.4412	1.0374	0.8145	1.0576	0.9973	0.8900	0.8642	0.8483	1.0315	1.2624	1.2769	1.2431					
NDVI (EnMAP)	0.6724	0.6442	0.6410	0.6258	0.5914	0.6394	0.6945	0.6608	0.5773	0.5220	0.5878	0.5679	0.5474	0.5319	0.5238	0.5657	0.6175	0.6150	0.6100					
Nadir Norm. NDVI (AVHRR)	1.0225	0.9835	0.9720	0.9528	0.9030	0.9705	1.0480	1.0083	0.8815	0.8069	0.9113	0.8840	0.8429	0.8212	0.8115	0.8810	0.9452	0.9426	0.9351					
Nadir Norm. NDVI (MODIS)	1.0248	0.9856	0.9744	0.9541	0.9050	0.9727	1.0493	1.0077	0.8820	0.8059	0.9100	0.8818	0.8418	0.8215	0.8101	0.8793	0.9463	0.9427	0.9363					
Nadir Norm. NDVI (EnMAP)	1.0351	0.9917	0.9866	0.9633	0.9103	0.9842	1.0691	1.0172	0.8886	0.8034	0.9048	0.8741	0.8426	0.8187	0.8063	0.8708	0.9505	0.9467	0.9390					

Table C.5-3: Spectro-directional data of the HVG1_02 spectro-goniometer measurement.

HVG1_02 (SZA = 50°; SAA = 139°)	Viewing Geometry (Viewing Zenith Angle | Viewing Azimuth Angle)																							
	0|0	5|180	5|202.5	5|225	5|270	5|315	5|337.5	5|0	5|22.5	5|45	5|90	5|135	5|157.5	10|180	10|190	10|202.5	10|225	10|270	10|315	10|337.5	10|350
HCRF EnMAP blue (479 nm)	0.0514	0.0379	0.0481	0.0619	0.0551	0.0680	0.0410	0.0423	0.0437	0.0485	0.0472	0.0432	0.0385	0.0351	0.0355	0.0365	0.0568	0.0621	0.0617	0.0387	0.0373
HCRF EnMAP green (549 nm)	0.0921	0.0644	0.0786	0.0939	0.0903	0.0974	0.0649	0.0682	0.0731	0.0822	0.0877	0.0796	0.0771	0.0701	0.0680	0.0667	0.0933	0.0992	0.0953	0.0587	0.0585
HCRF EnMAP rot (672 nm)	0.0932	0.0608	0.0731	0.0910	0.0844	0.1057	0.0651	0.0731	0.0782	0.0891	0.0845	0.0764	0.0647	0.0595	0.0571	0.0598	0.0890	0.0964	0.0985	0.0624	0.0621
HCRF EnMAP NIR (864 nm)	0.3461	0.2313	0.2785	0.3146	0.3374	0.2876	0.2328	0.2493	0.2664	0.2968	0.3444	0.3078	0.3095	0.2781	0.2661	0.2729	0.3485	0.3583	0.3057	0.2005	0.2158
ANIF EnMAP rot (672 nm)	1.0000	0.6521	0.7847	0.9762	0.9061	1.1337	0.6984	0.7844	0.8389	0.9557	0.9068	0.8200	0.6937	0.6388	0.6126	0.6414	0.9550	1.0340	1.0569	0.6692	0.6669
ANIF EnMAP NIR (864 nm)	1.0000	0.6684	0.8047	0.9089	0.9749	0.8310	0.6727	0.7203	0.7698	0.8574	0.9951	0.8894	0.8943	0.8034	0.7687	0.7885	1.0070	1.0351	0.8833	0.5792	0.6234
Rel. Blue Absorption Depth	0.4663	0.4245	0.4329	0.3964	0.4272	0.3242	0.3717	0.3873	0.4080	0.4174	0.4861	0.4873	0.5397	0.5324	0.5044	0.4874	0.4393	0.4232	0.3651	0.3365	0.3538
Rel. Red Absorption Depth	1.0909	1.1144	1.1291	0.9719	1.1444	0.6776	0.9638	0.9542	0.9589	0.9497	1.2316	1.2263	1.4969	1.4435	1.4453	1.3807	1.1172	1.0374	0.8124	0.8396	0.9596
NDVI (EnMAP)	0.5757	0.5839	0.5841	0.5513	0.5997	0.4627	0.5631	0.5466	0.5463	0.5383	0.6060	0.6022	0.6544	0.6473	0.6466	0.6406	0.5932	0.5761	0.5127	0.5254	0.5527
Nadir Norm. NDVI (AVHRR)	1.0000	1.0083	1.0100	0.9405	1.0351	0.8055	0.9661	0.9504	0.9547	0.9470	1.0471	1.0487	1.1117	1.1061	1.1056	1.1035	1.0096	0.9880	0.8844	0.9116	0.9589
Nadir Norm. NDVI (MODIS)	1.0000	1.0109	1.0152	0.9430	1.0345	0.8045	0.9639	0.9466	0.9513	0.9436	1.0478	1.0499	1.1154	1.1085	1.1097	1.1064	1.0120	0.9871	0.8837	0.9086	0.9556
Nadir Norm. NDVI (EnMAP)	1.0000	1.0142	1.0145	0.9577	1.0416	0.8037	0.9780	0.9493	0.9488	0.9350	1.0525	1.0460	1.1367	1.1243	1.1232	1.1127	1.0303	1.0006	0.8905	0.9126	0.9601

(cont.)

HVG1_02 (SZA = 50°; SAA = 139°)	Viewing Geometry (Viewing Zenith Angle | Viewing Azimuth Angle)																							
	10|0	10|10	10|22.5	10|45	10|90	10|135	10|157.5	10|170	20|180	20|190	20|202.5	20|225	20|270	20|315	20|337.5	20|350	20|0	20|10	20|22.5	20|45	20|90
HCRF EnMAP blue (479 nm)	0.0409	0.0399	0.0406	0.0474	0.0485	0.0470	0.0413	0.0396	0.0488	0.0478	0.0612	0.0594	0.0525	0.0452	0.0368	0.0386	0.0418	0.0409	0.0374	0.0362	0.0356
HCRF EnMAP green (549 nm)	0.0652	0.0666	0.0679	0.0771	0.0864	0.0858	0.0833	0.0796	0.0892	0.0935	0.1030	0.1055	0.0861	0.0693	0.0546	0.0588	0.0645	0.0658	0.0633	0.0591	0.0664
HCRF EnMAP rot (672 nm)	0.0714	0.0698	0.0704	0.0842	0.0839	0.0838	0.0721	0.0678	0.0826	0.0794	0.1000	0.1019	0.0892	0.0693	0.0579	0.0631	0.0692	0.0695	0.0635	0.0630	0.0640
HCRF EnMAP NIR (864 nm)	0.2427	0.2519	0.2514	0.2720	0.3313	0.3240	0.3371	0.3221	0.3222	0.3515	0.3503	0.4141	0.3296	0.2315	0.1953	0.2109	0.2333	0.2433	0.2369	0.2188	0.2833
ANIF EnMAP rot (672 nm)	0.7659	0.7490	0.7552	0.9035	0.9008	0.8996	0.7736	0.7273	0.8867	0.8518	1.0726	1.0931	0.9573	0.7432	0.6211	0.6774	0.7422	0.7458	0.6811	0.6763	0.6869
ANIF EnMAP NIR (864 nm)	0.7012	0.7278	0.7263	0.7860	0.9572	0.9361	0.9738	0.9305	0.9309	1.0155	1.0120	1.1964	0.9524	0.6689	0.5642	0.6093	0.6741	0.7028	0.6843	0.6320	0.8184
Rel. Blue Absorption Depth	0.3780	0.4056	0.4080	0.3862	0.4591	0.4855	0.5618	0.5517	0.4937	0.5475	0.4529	0.5005	0.4202	0.3573	0.3276	0.3498	0.3539	0.3800	0.4088	0.3841	0.4825
Rel. Red Absorption Depth	0.9527	1.0164	1.0235	0.9099	1.1762	1.1684	1.4777	1.4912	1.1739	1.3745	1.0179	1.2022	1.0207	0.8785	0.8998	0.9077	0.9269	0.9866	1.0750	0.9840	1.3609
NDVI (EnMAP)	0.5455	0.5660	0.5625	0.5273	0.5957	0.5889	0.6476	0.6523	0.5918	0.6315	0.5560	0.6051	0.5740	0.5394	0.5427	0.5392	0.5427	0.5556	0.5773	0.5527	0.6313
Nadir Norm. NDVI (AVHRR)	0.9545	0.9822	0.9786	0.9303	1.0321	1.0254	1.1085	1.1109	1.0169	1.0818	0.9610	1.0335	0.9954	0.9286	0.9455	0.9390	0.9461	0.9660	1.0010	0.9681	1.0972
Nadir Norm. NDVI (MODIS)	0.9500	0.9787	0.9766	0.9268	1.0333	1.0261	1.1108	1.1138	1.0205	1.0862	0.9636	1.0322	0.9933	0.9270	0.9425	0.9356	0.9428	0.9636	1.0014	0.9651	1.0978
Nadir Norm. NDVI (EnMAP)	0.9475	0.9831	0.9771	0.9158	1.0347	1.0228	1.1248	1.1329	1.0278	1.0969	0.9657	1.0511	0.9970	0.9369	0.9426	0.9366	0.9427	0.9650	1.0027	0.9599	1.0966

(cont.)

HVG1_02 (SZA = 50°; SAA = 139°)	Viewing Geometry (Viewing Zenith Angle | Viewing Azimuth Angle)																							
	20|135	20|157.5	20|170	30|180	30|190	30|202.5	30|225	30|270	30|315	30|337.5	30|350	30|0	30|10	30|22.5	30|45	30|90	30|135	30|157.5	30|170			
HCRF EnMAP blue (479 nm)	0.0413	0.0495	0.0514	0.0638	0.0491	0.0517	0.0683	0.0529	0.0408	0.0324	0.0363	0.0396	0.0354	0.0394	0.0364	0.0386	0.0534	0.0585	0.0615					
HCRF EnMAP green (549 nm)	0.0816	0.0940	0.0958	0.1281	0.1032	0.1099	0.1239	0.0828	0.0615	0.0477	0.0559	0.0606	0.0541	0.0603	0.0545	0.0695	0.1036	0.1179	0.1185					
HCRF EnMAP rot (672 nm)	0.0739	0.0891	0.0891	0.1177	0.0924	0.0910	0.1173	0.0913	0.0646	0.0508	0.0576	0.0623	0.0590	0.0673	0.0628	0.0685	0.0973	0.1086	0.1172					
HCRF EnMAP NIR (864 nm)	0.3246	0.3410	0.3407	0.4631	0.4051	0.4442	0.4714	0.3201	0.2116	0.1816	0.2134	0.2227	0.1987	0.2093	0.1889	0.2796	0.3898	0.4341	0.4180					
ANIF EnMAP rot (672 nm)	0.7930	0.9564	0.9557	1.2631	0.9919	0.9761	1.2588	0.9792	0.6929	0.5450	0.6185	0.6688	0.6327	0.7221	0.6742	0.7350	1.0436	1.1656	1.2574					
ANIF EnMAP NIR (864 nm)	0.9378	0.9851	0.9843	1.3379	1.1704	1.2832	1.3619	0.9249	0.6115	0.5248	0.6166	0.6434	0.5741	0.6047	0.5459	0.8078	1.1263	1.2543	1.2077					
Rel. Blue Absorption Depth	0.5345	0.5150	0.5069	0.5660	0.6003	0.6187	0.5158	0.3820	0.3299	0.3214	0.3566	0.3400	0.3324	0.3364	0.3181	0.4585	0.5284	0.5626	0.5300					
Rel. Red Absorption Depth	1.3670	1.1432	1.1456	1.1822	1.3527	1.5233	1.1859	0.9938	0.8679	0.9788	1.0396	1.0015	0.9031	0.8546	0.8205	1.2425	1.2305	1.2129	1.0594					
NDVI (EnMAP)	0.6291	0.5855	0.5855	0.5946	0.6284	0.6600	0.6014	0.5563	0.5325	0.5630	0.5747	0.5626	0.5424	0.5134	0.5008	0.6065	0.6007	0.5997	0.5621					
Nadir Norm. NDVI (AVHRR)	1.0800	1.0052	1.0059	1.0141	1.0824	1.1242	1.0259	0.9721	0.9321	0.9833	0.9852	0.9694	0.9489	0.9067	0.8908	1.0514	1.0365	1.0276	0.9700					
Nadir Norm. NDVI (MODIS)	1.0830	1.0062	1.0090	1.0165	1.0837	1.1276	1.0278	0.9673	0.9309	0.9820	0.9839	0.9693	0.9462	0.9030	0.8863	1.0513	1.0382	1.0294	0.9708					
Nadir Norm. NDVI (EnMAP)	1.0927	1.0170	1.0170	1.0328	1.0915	1.1464	1.0447	0.9663	0.9249	0.9778	0.9982	0.9772	0.9421	0.8918	0.8699	1.0534	1.0433	1.0417	0.9763					

Table C.5-4: Spectro-directional data of the HVG1_03 spectro-goniometer measurement.

HVG1_03 (SZA = 46°; SAA = 179°)	Viewing Geometry (Viewing Zenith Angle | Viewing Azimuth Angle)																							
	0|0	5|180	5|202.5	5|225	5|270	5|315	5|337.5	5|0	5|22.5	5|45	5|90	5|135	5|157.5	10|180	10|202.5	10|225	10|270	10|315	10|337.5	10|350
HCRF EnMAP blue (479 nm)	0.0334	0.0282	0.0277	0.0299	0.0469	0.0274	0.0261	0.0278	0.0338	0.0276	0.0281	0.0287	0.0282	0.0209	0.0193	0.0264	0.0517	0.0281	0.0244	0.0256
HCRF EnMAP green (549 nm)	0.0650	0.0441	0.0408	0.0466	0.0641	0.0435	0.0433	0.0492	0.0593	0.0546	0.0526	0.0535	0.0449	0.0372	0.0361	0.0467	0.0719	0.0448	0.0413	0.0437
HCRF EnMAP rot (672 nm)	0.0638	0.0414	0.0393	0.0422	0.0687	0.0426	0.0429	0.0483	0.0630	0.0472	0.0494	0.0446	0.0411	0.0349	0.0308	0.0390	0.0756	0.0444	0.0408	0.0442
HCRF EnMAP NIR (864 nm)	0.2781	0.1600	0.1407	0.1624	0.1764	0.1572	0.1634	0.2024	0.2426	0.2526	0.2341	0.2158	0.1698	0.1490	0.1568	0.1621	0.1912	0.2009	0.1626	0.1618	0.1773
ANIF EnMAP rot (672 nm)	1.0000	0.6495	0.6165	0.6611	1.0775	0.6680	0.6729	0.7570	0.9874	0.7397	0.7750	0.6988	0.6443	0.5470	0.5268	0.4828	0.6109	1.1857	0.6965	0.6394	0.6938
ANIF EnMAP NIR (864 nm)	1.0000	0.5754	0.5058	0.5838	0.6342	0.5651	0.5875	0.7278	0.8724	0.9081	0.8418	0.7761	0.6107	0.5358	0.5638	0.5829	0.6876	0.7223	0.5846	0.5819	0.6377
Rel. Blue Absorption Depth	0.5277	0.3876	0.3504	0.3930	0.3192	0.3772	0.4039	0.4553	0.4542	0.5456	0.4915	0.5026	0.4010	0.4544	0.4633	0.4875	0.4718	0.3192	0.3848	0.4179	0.4263
Rel. Red Absorption Depth	1.3011	1.1320	0.9902	1.1029	0.6149	1.0159	1.0640	1.2220	1.1400	1.6703	1.4535	1.4768	1.2106	1.2651	1.3831	1.5861	1.4425	0.6424	1.0031	1.1229	1.1418
NDVI (EnMAP)	0.6270	0.5888	0.5632	0.5878	0.4393	0.5735	0.5840	0.6149	0.5879	0.6853	0.6514	0.6578	0.6104	0.6207	0.6471	0.6808	0.6616	0.4531	0.5709	0.5975	0.6007
Nadir Norm. NDVI (AVHRR)	1.0000	0.9276	0.8789	0.9170	0.6997	0.9075	0.9303	0.9762	0.9462	1.0793	1.0308	1.0216	0.9606	0.9812	1.0107	1.0565	1.0353	0.7177	0.9060	0.9512	0.9605
Nadir Norm. NDVI (MODIS)	1.0000	0.9351	0.8849	0.9204	0.7004	0.9089	0.9308	0.9773	0.9444	1.0818	1.0334	1.0303	0.9699	0.9845	1.0149	1.0596	1.0373	0.7182	0.9061	0.9529	0.9611
Nadir Norm. NDVI (EnMAP)	1.0000	0.9391	0.8983	0.9375	0.7007	0.9148	0.9315	0.9807	0.9377	1.0930	1.0390	1.0491	0.9736	0.9899	1.0321	1.0858	1.0552	0.7227	0.9106	0.9530	0.9581

(cont.)

HVG1_03 (SZA = 46°; SAA = 179°)	Viewing Geometry (Viewing Zenith Angle | Viewing Azimuth Angle)																							
	10|0	10|10	10|22.5	10|45	10|90	10|135	10|157.5	10|170	20|180	20|190	20|202.5	20|225	20|270	20|315	20|337.5	20|350	20|0	20|10	20|22.5	20|45	20|90
HCRF EnMAP blue (479 nm)	0.0285	0.0327	0.0322	0.0246	0.0295	0.0239	0.0266	0.0253	0.0451	0.0413	0.0304	0.0329	0.0321	0.0232	0.0203	0.0207	0.0220	0.0239	0.0267	0.0242	0.0246
HCRF EnMAP green (549 nm)	0.0513	0.0566	0.0590	0.0460	0.0549	0.0474	0.0460	0.0403	0.0731	0.0682	0.0606	0.0627	0.0504	0.0365	0.0347	0.0352	0.0371	0.0394	0.0438	0.0424	0.0477
HCRF EnMAP rot (672 nm)	0.0497	0.0583	0.0596	0.0414	0.0516	0.0380	0.0388	0.0375	0.0720	0.0674	0.0530	0.0563	0.0495	0.0360	0.0332	0.0351	0.0375	0.0419	0.0472	0.0428	0.0413
HCRF EnMAP NIR (864 nm)	0.2220	0.2339	0.2552	0.2156	0.2336	0.2025	0.1826	0.1491	0.2493	0.2405	0.2589	0.2701	0.1742	0.1446	0.1449	0.1509	0.1661	0.1725	0.1864	0.1925	0.2159
ANIF EnMAP rot (672 nm)	0.7795	0.9144	0.9345	0.6497	0.8086	0.5959	0.6078	0.5888	1.1292	1.0572	0.8305	0.8832	0.7766	0.5646	0.5208	0.5509	0.5882	0.6564	0.7396	0.6708	0.6472
ANIF EnMAP NIR (864 nm)	0.7984	0.8410	0.9176	0.7753	0.8399	0.7282	0.6565	0.5362	0.8964	0.8647	0.9311	0.9712	0.6264	0.5199	0.5212	0.5427	0.5974	0.6202	0.6702	0.6923	0.7762
Rel. Blue Absorption Depth	0.4689	0.4369	0.4856	0.4957	0.4872	0.5432	0.4501	0.3899	0.4404	0.4395	0.5541	0.5216	0.3773	0.3622	0.4057	0.4064	0.4031	0.3909	0.3858	0.4326	0.5113
Rel. Red Absorption Depth	1.3177	1.1670	1.2947	1.5972	1.3689	1.6483	1.4280	1.1520	0.9860	1.0084	1.4570	1.4122	0.9262	1.1080	1.2472	1.2468	1.2811	1.1834	1.1457	1.3579	1.6137
NDVI (EnMAP)	0.6342	0.6009	0.6214	0.6777	0.6384	0.6840	0.6498	0.5978	0.5518	0.5621	0.6604	0.6550	0.5573	0.6013	0.6272	0.6224	0.6317	0.6094	0.5961	0.6365	0.6790
Nadir Norm. NDVI (AVHRR)	1.0052	0.9602	0.9927	1.0708	1.0057	1.0578	1.0177	0.9434	0.8708	0.8889	1.0285	1.0240	0.8727	0.9465	0.9908	0.9926	1.0050	0.9755	0.9600	1.0169	1.0603
Nadir Norm. NDVI (MODIS)	1.0058	0.9591	0.9926	1.0725	1.0094	1.0656	1.0259	0.9504	0.8757	0.8918	1.0302	1.0240	0.8724	0.9473	0.9927	0.9927	1.0048	0.9753	0.9595	1.0175	1.0654
Nadir Norm. NDVI (EnMAP)	1.0116	0.9584	0.9911	1.0808	1.0182	1.0910	1.0364	0.9534	0.8802	0.8965	1.0533	1.0446	0.8889	0.9591	1.0004	0.9927	1.0075	0.9720	0.9508	1.0151	1.0830

(cont.)

HVG1_03 (SZA = 46°; SAA = 179°)	Viewing Geometry (Viewing Zenith Angle | Viewing Azimuth Angle)																							
	20|135	20|157.5	20|170	30|180	30|190	30|202.5	30|225	30|270	30|315	30|337.5	30|350	30|0	30|10	30|22.5	30|45	30|90	30|135	30|157.5	30|170			
HCRF EnMAP blue (479 nm)	0.0455	0.0524	0.0493	0.0408	0.0499	0.0529	0.0423	0.0420	0.0318	0.0257	0.0228	0.0207	0.0203	0.0245	0.0250	0.0321	0.0408	0.0370	0.0408					
HCRF EnMAP green (549 nm)	0.0747	0.0852	0.0772	0.0907	0.0906	0.0940	0.0694	0.0624	0.0448	0.0392	0.0372	0.0330	0.0325	0.0405	0.0419	0.0625	0.0867	0.0835	0.0861					
HCRF EnMAP rot (672 nm)	0.0700	0.0766	0.0737	0.0728	0.0830	0.0858	0.0737	0.0676	0.0477	0.0389	0.0361	0.0337	0.0333	0.0422	0.0433	0.0579	0.0760	0.0666	0.0753					
HCRF EnMAP NIR (864 nm)	0.2521	0.2835	0.2464	0.3792	0.3397	0.3507	0.2861	0.1953	0.1565	0.1528	0.1560	0.1382	0.1417	0.1758	0.1863	0.2758	0.3551	0.3540	0.3563					
ANIF EnMAP rot (672 nm)	1.0984	1.2019	1.1559	1.1412	1.3013	1.3455	1.1551	1.0595	0.7482	0.6093	0.5664	0.5292	0.5226	0.6616	0.6788	0.9087	1.1917	1.0445	1.1814					
ANIF EnMAP NIR (864 nm)	0.9065	1.0193	0.8860	1.3633	1.2215	1.2611	1.0286	0.7023	0.5627	0.5494	0.5608	0.4968	0.5095	0.6321	0.6700	0.9919	1.2770	1.2729	1.2812					
Rel. Blue Absorption Depth	0.4409	0.4410	0.4141	0.6673	0.5155	0.5075	0.4187	0.3327	0.3139	0.3455	0.3817	0.3617	0.3570	0.3890	0.3965	0.5294	0.6142	0.6699	0.6185					
Rel. Red Absorption Depth	1.0443	1.0689	0.9284	1.6331	1.2049	1.1673	1.1229	0.7558	0.8503	1.0777	1.2349	1.1481	1.1881	1.2072	1.2679	1.4656	1.4356	1.6548	1.4627					
NDVI (EnMAP)	0.5652	0.5744	0.5395	0.6780	0.6074	0.6069	0.5905	0.4860	0.5327	0.5945	0.6239	0.6074	0.6193	0.6129	0.6230	0.6528	0.6475	0.6833	0.6510					
Nadir Norm. NDVI (AVHRR)	0.8888	0.8951	0.8441	1.0541	0.9414	0.9409	0.9400	0.7858	0.8428	0.9330	0.9796	0.9667	0.9838	0.9815	0.9985	1.0297	1.0059	1.0586	1.0186					
Nadir Norm. NDVI (MODIS)	0.8972	0.9038	0.8514	1.0582	0.9456	0.9450	0.9356	0.7850	0.8445	0.9352	0.9829	0.9678	0.9841	0.9817	0.9983	1.0334	1.0105	1.0622	1.0206					
Nadir Norm. NDVI (EnMAP)	0.9014	0.9161	0.8605	1.0813	0.9688	0.9680	0.9418	0.7752	0.8496	0.9483	0.9951	0.9688	0.9877	0.9776	0.9937	1.0413	1.0327	1.0899	1.0383					

V *Main Spectral Characteristics*

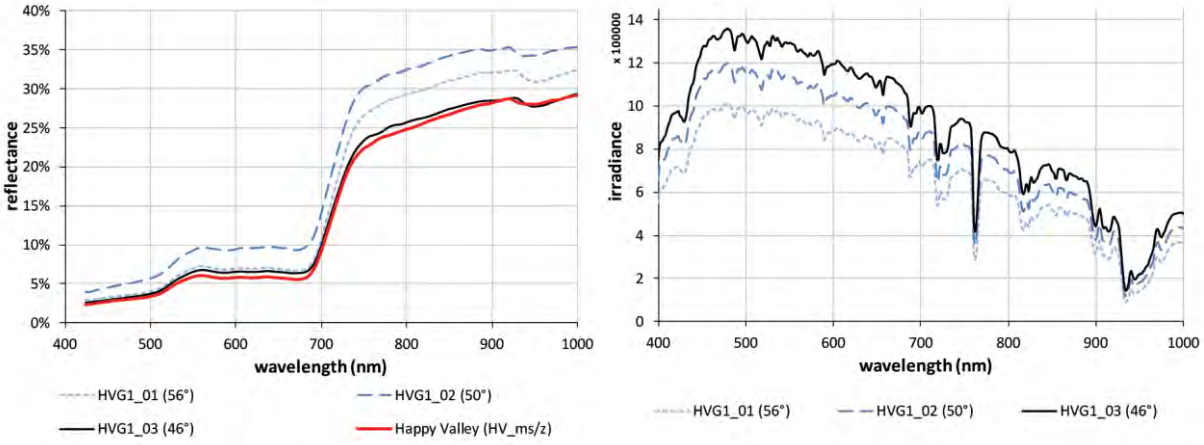

Figure C.5-6: Nadir reflectances and irradiance profiles of the HVG1 site at different sun zenith angles. Left: Comparison of the nadir reflectance signatures with the average zonal vegetation (MAT). Right: Comparison of the total irradiance profiles.

VI *HCRF Visualization*

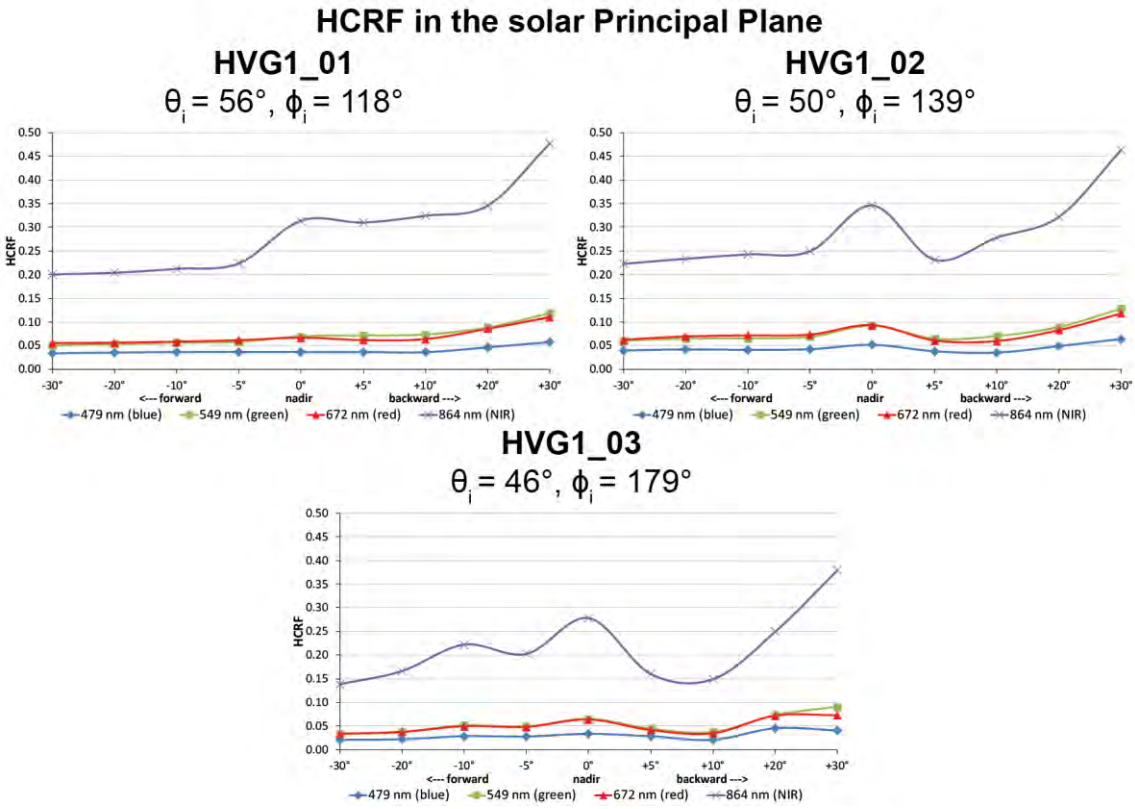

Figure C.5-7: Comparison of the HCRF values at 479 nm (blue), 549 nm (green), 672 nm (red), and 864 nm (NIR) in the solar principal plane of the HVG1 site at different sun zenith angles.

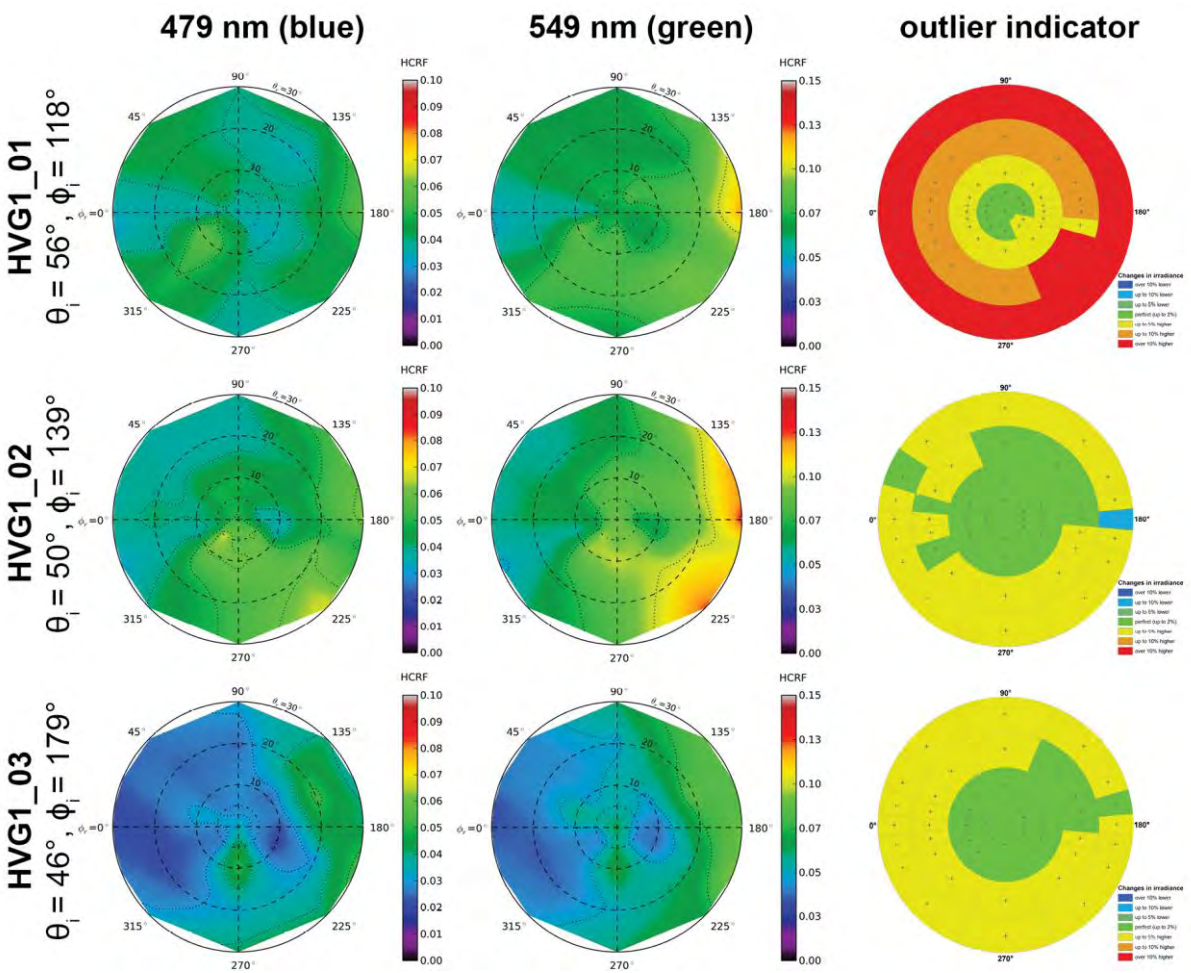

Figure C.5-8: HCRF visualization at 479 nm and 549 nm of the HVG1 site.

Figure C.5-9: Legend of the outlier indicator graphics shown in Figure C.5-8, C.5-10, and C.5-13

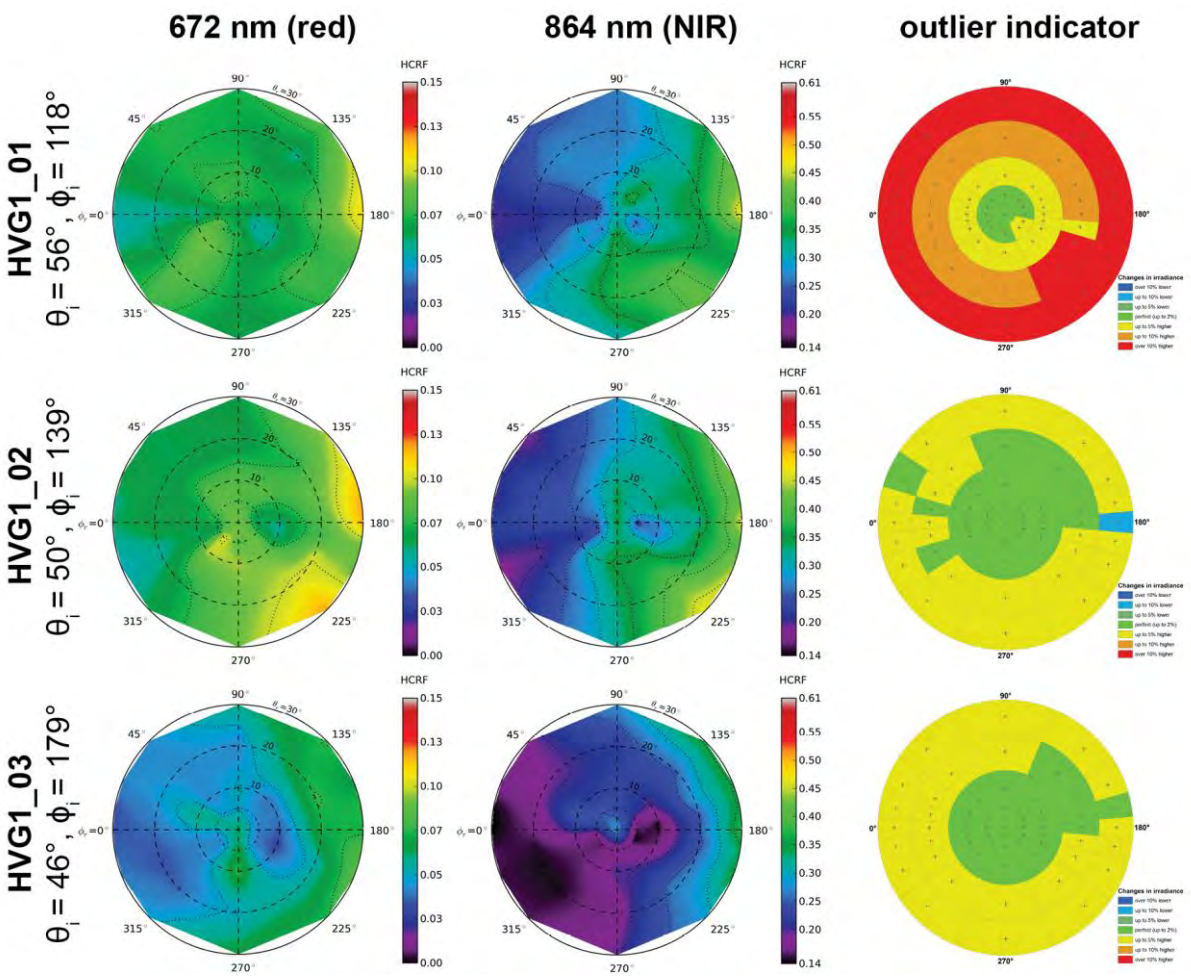

Figure C.5-10: HCRF visualization at 672 nm and 864 nm of the HVG1 site.

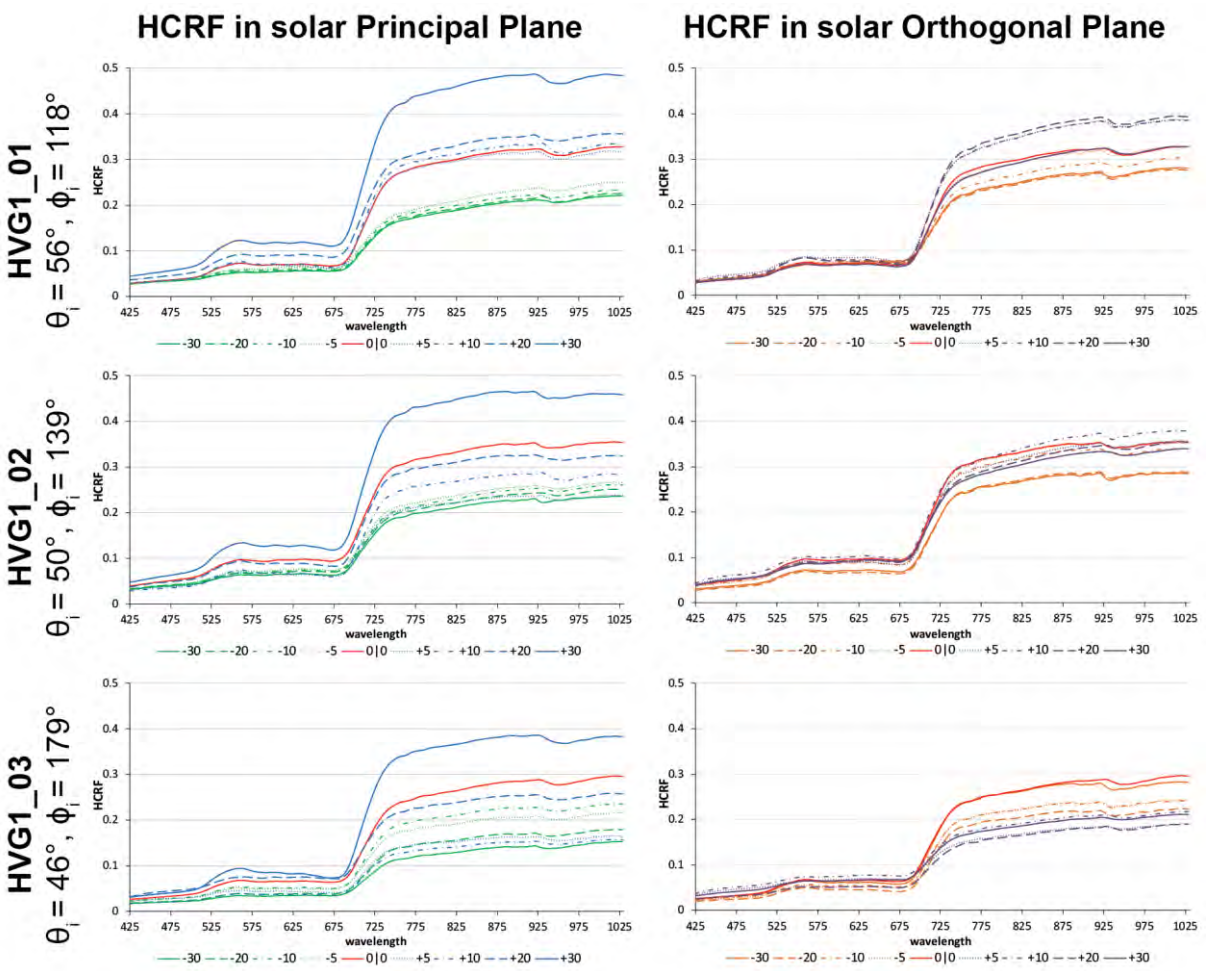

Figure C.5-11: HCRF visualization in principal & orthogonal plane of the HVG1 site.

VII *ANIF Visualization*

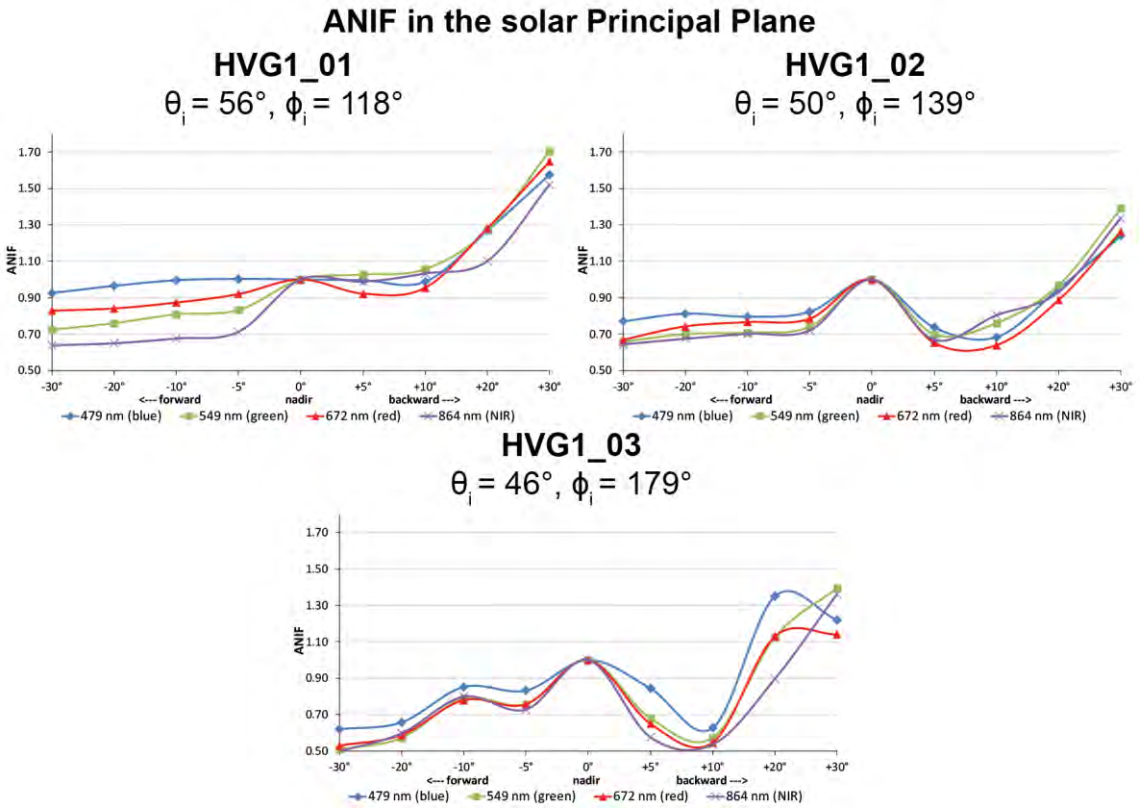

Figure C.5-12: Comparison of the ANIF values at 479 nm (blue), 549 nm (green), 672 nm (red), and 864 nm (NIR) in the solar principal plane of the HVG1 site at different sun zenith angles.

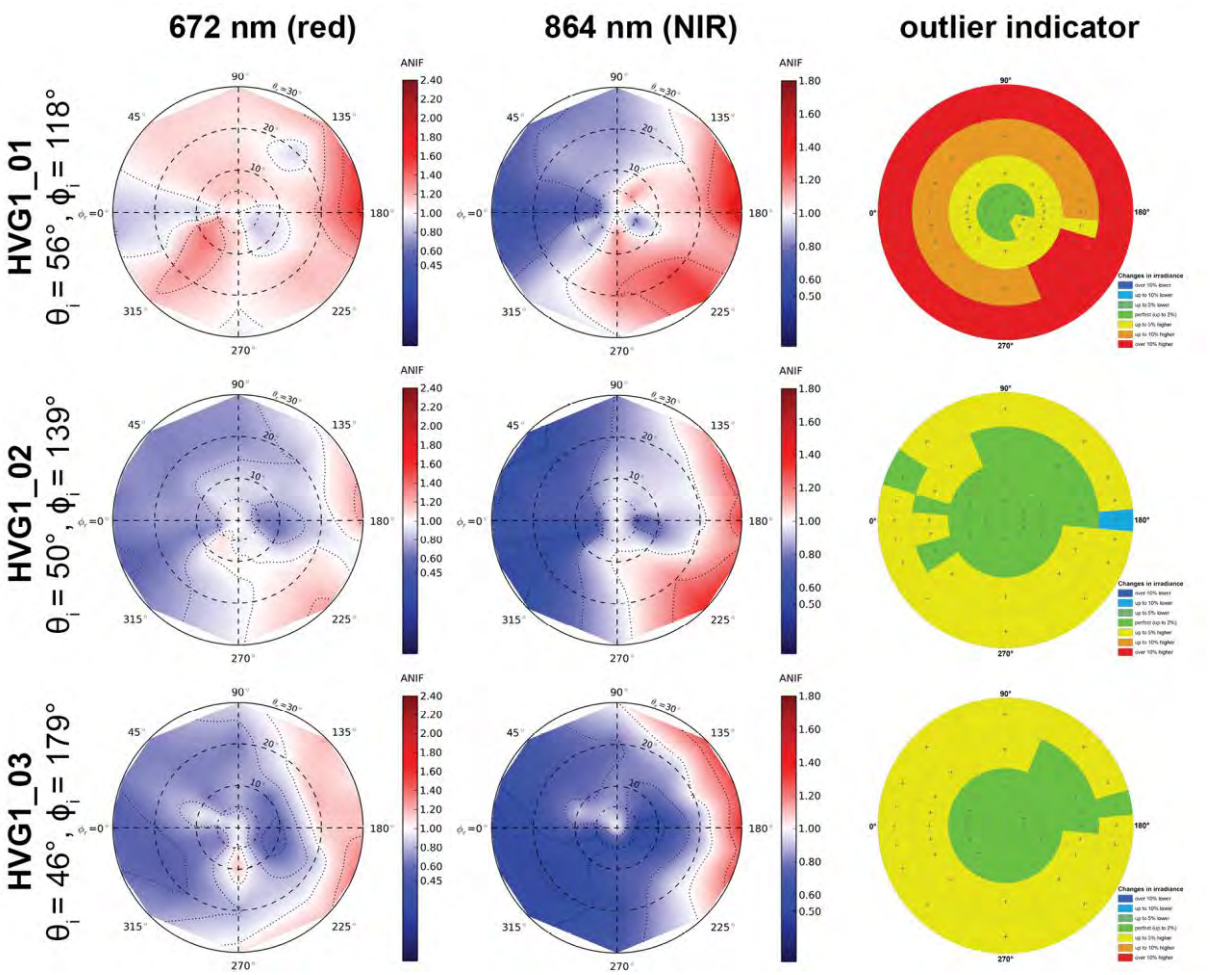

Figure C.5-13: ANIF visualization at 672 nm and 864 nm of the HVG1 site.

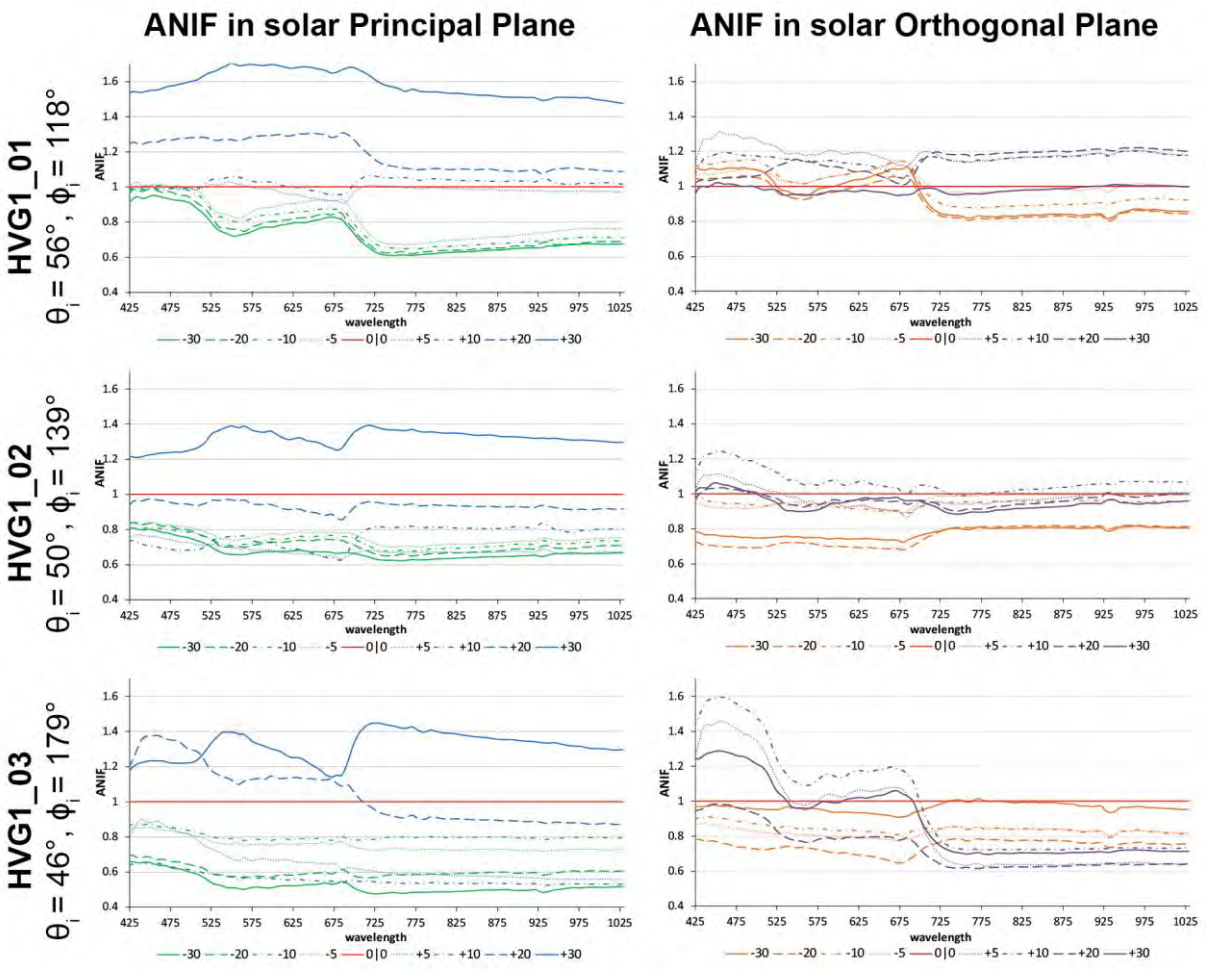

Figure C.5-14: ANIF visualization in principal & orthogonal plane of the HVG1 site.

VIII *ANIX Visualization*

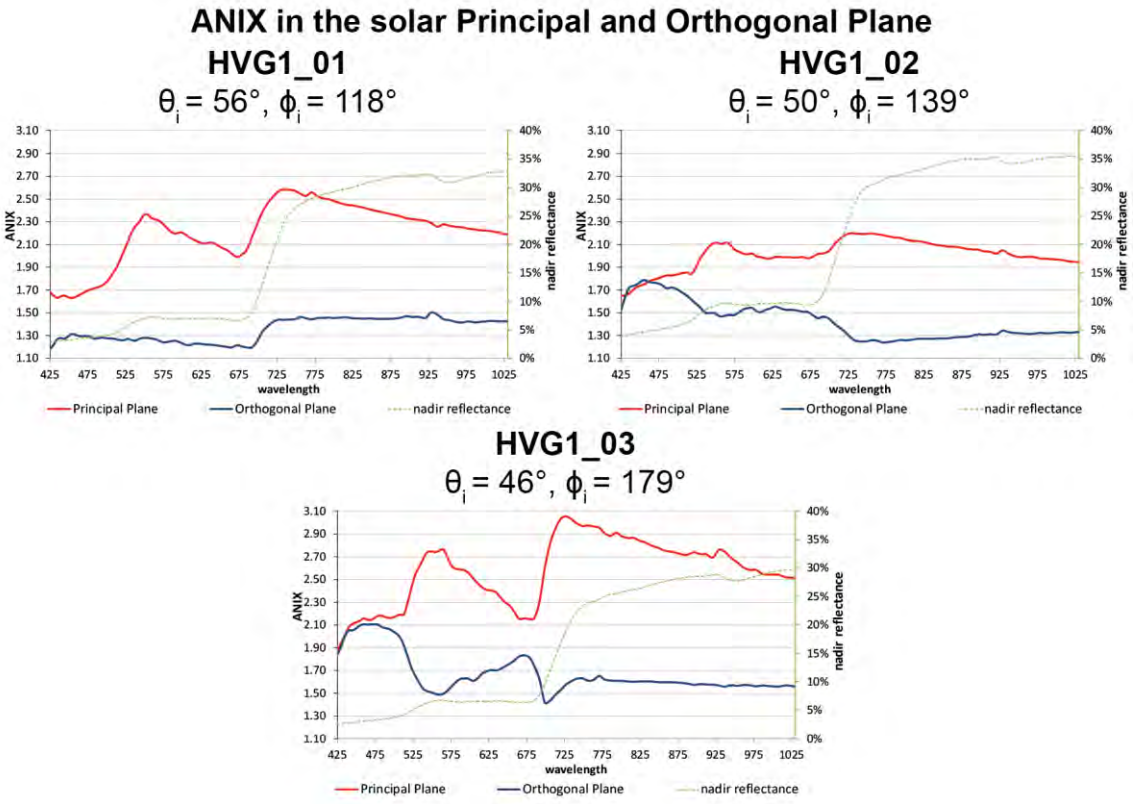

Figure C.5-15: Comparison of the ANIX in the solar principal and orthogonal plane with the nadir reflectance of the HVG1 site at different sun zenith angles.

IX *NDVI and Relative Absorption Depth Visualization*

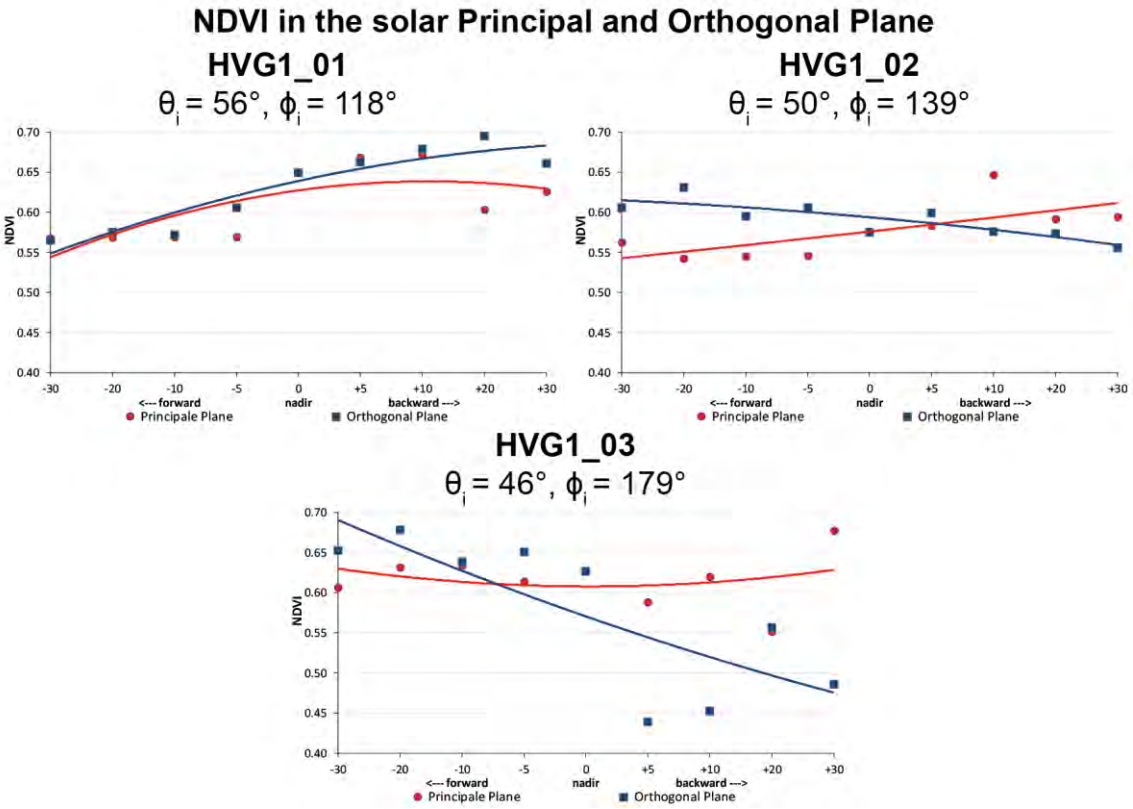

Figure C.5-16: Comparison of the NDVI in the solar principal and orthogonal plane of the HVG1 site at different sun zenith angles.

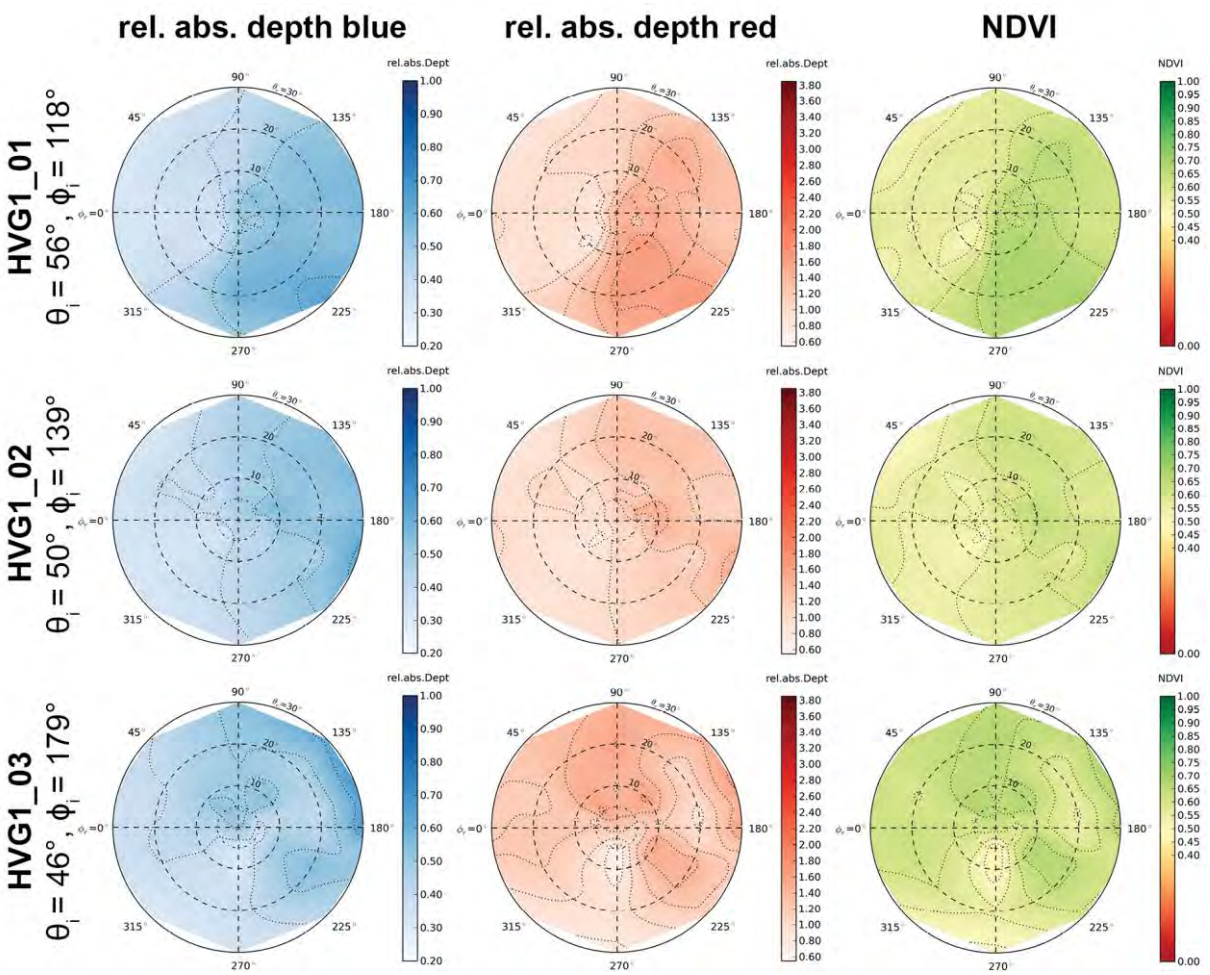

Figure C.5-17: Visualization of relative absorption depth & NDVI of the HVG1 site.

X *NDVI Comparison of Different Sensors*

Table C.5-5: Center wavelengths and band widths of the broadband and narrowband NDVIs, based on the spectral response curves of the AVHRR, MODIS and EnMAP sensors.

NDVI	Sensor	Sensor band	Center wavelength (nm)	band width (nm)
$NDVI_{AVHRR}$ [broadband]	AVHRR/3	red: band 1 NIR: band 2	630 865	100 275
$NDVI_{MODIS}$ [broadband]	MODIS	red: band 1 NIR: band 2	645 859	50 35
$NDVI_{EnMAP}$ [narrowband]	EnMAP	red: band 47 NIR: band 73	672 864	6.5 8

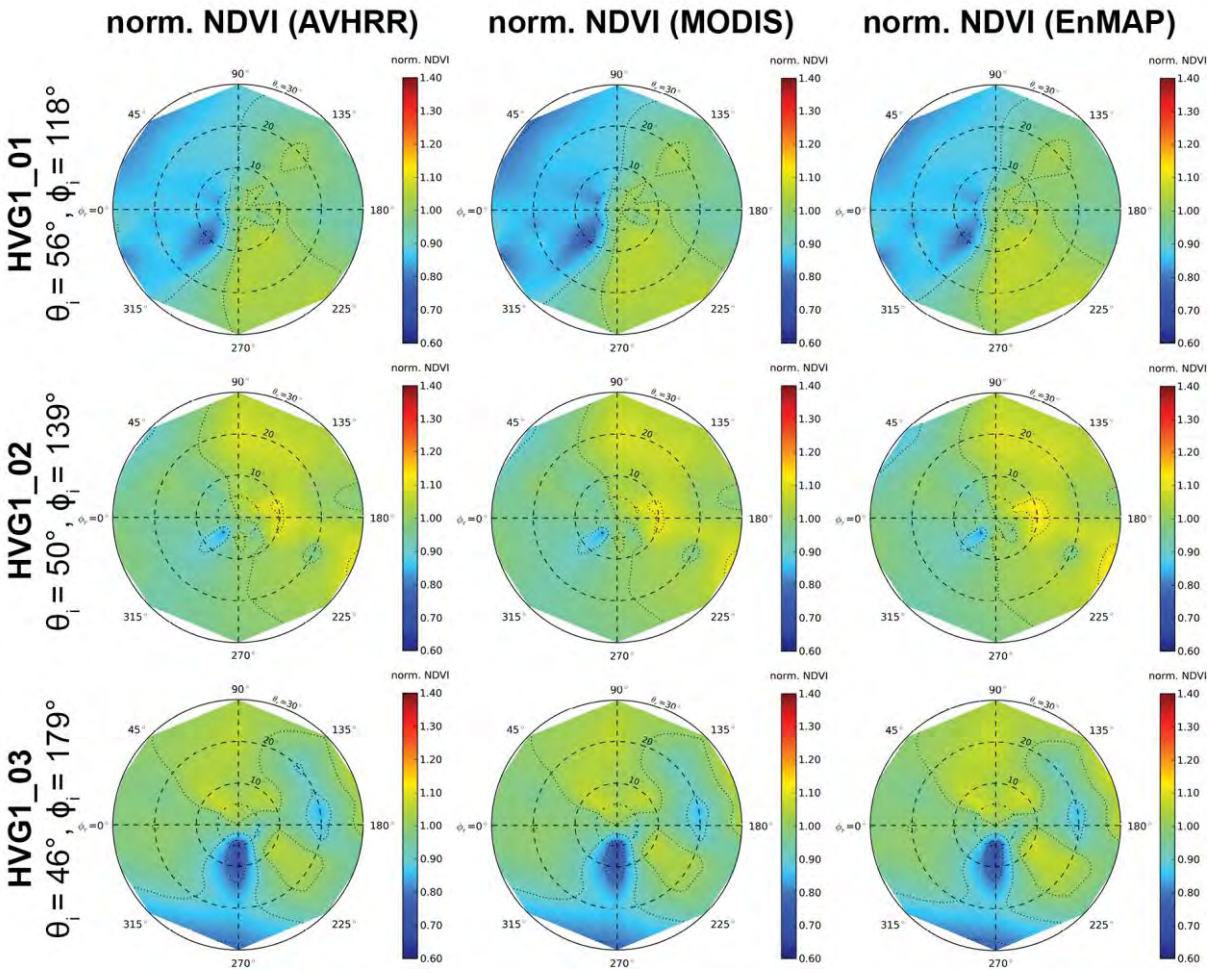

Figure C.5-18: Comparison of AVHRR, MODIS & EnMAP NDVI of the HVG1 site.