

C.4 Study site FBG4 (horsetail community)

I Location

Name	Location	Latitude	Longitude	Altitude
FBG4	Franklin Bluffs, Arctic North Slope, Alaska, United States of America	69.6744°	-148.72022°	125 m

At an average elevation of 90 m, Franklin Bluffs is located in Subzone D about 1 km west of the Dalton Highway across from the pipeline access road APL/AMS 130 near green mile marker 375. This access road provides parking at the site. Three 10 x 10 m grids, designated dry, mesic, and wet, have been established at this location in 2002. The goniometer measurements have been carried out next to the moist / zonal site (FB_m/z). [Barreda *et al.*, 2006]

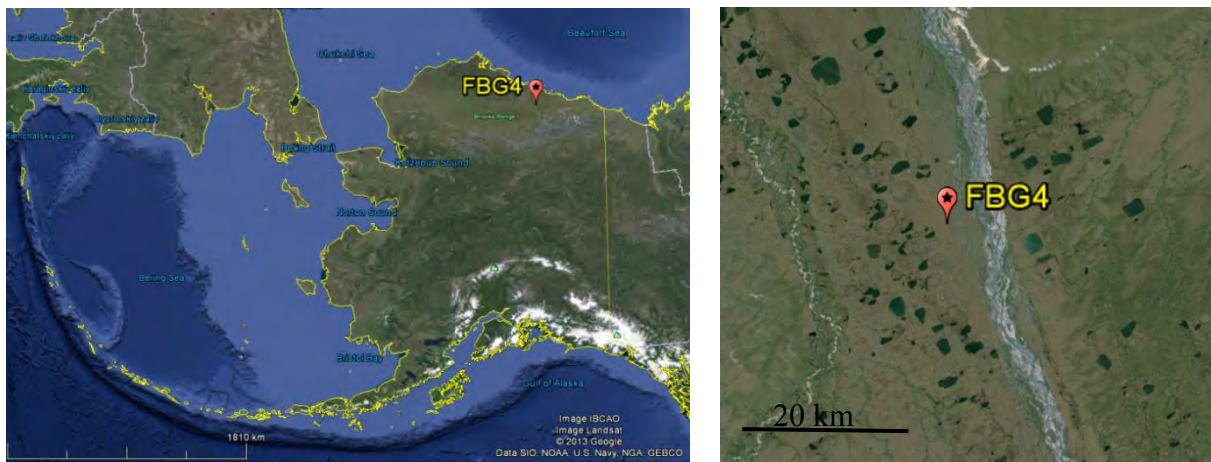


Figure C.4-1: Location of study site FBG4 in Alaska, USA. *Source:* Google Earth, 2013



Figure C.4-2: Aerial photo of a 10 x 10 m zonal grid at the Franklin Bluffs study location near the FBG4 site. *Source:* [Barreda *et al.*, 2006]

II Main Vegetation Description

The vegetation at the mesic Franklin Bluffs study location corresponds to the zonal vegetation in subzone D. The zonal plant community of bioclimate subzone D in northern Alaska is *Dryado integrifoliae-Caricetum bigelowii* [Walker et al., 2005], also called moist non-acidic tundra (MNT), or ‘nontussock sedge, dwarf-shrub, moss tundra’ [Walker et al., 2005]. It occurs on circumneutral to basic soils in association with silty loess that is blown from the major rivers in the eastern part of the Arctic Coastal Plain. The average soil pH of this plant community at Franklin Bluffs is 7.9; the average volumetric soil moisture of the top mineral horizon is 45 %, and average depth of thaw by late summer is 40 cm [Kade et al., 2005]. The dominant plants in MNT are sedges (*Carex bigelowii*, *Eriophorum angustifolium* ssp. *triste*, *C. membranacea*, *C. scirpoidea*, *E. vaginatum*), prostrate and hemi-prostrate evergreen dwarf shrubs (*Dryas integrifolia*, *Cassiope tetragona*), prostrate dwarf deciduous shrubs (*Salix arctica*, *S. reticulata*, *Arctous rubra*), scattered erect dwarf deciduous shrubs (*Salix lanata*, *S. glauca*), several forbs (*Papaver macounii*, *Pedicularis lanata*, *Saussurea angustifolia*, *Senecio atropurpureus*, *Pedicularis capitata*, *Polygonum viviparum*, *Cardamine hyperborea*, *Astragalus umbellatus*), mosses (*Tomentypnum nitens*, *Hylocomium splendens*, *Aulacomnium turgidum*, *Rhytidium rugosum*, *Hypnum bambergeri*, *Distichium capillaceum*, *Ditrichum flexicaule*), and lichens (*Thamnolia subuliformis*, *Cetraria* spp.).

An important component of the MNT is the abundant nonsorted circles, also called frost boils, which are small patterned ground features caused by soil frost heave [Walker et al., 2008; Washburn, 1980]. These features cover large parts of most MNT surfaces. The 10 x 10 m zonal grid at Franklin Bluffs has about 30 % cover of nonsorted circles. These features have drier plant communities than the mesic zonal plant communities between the circles, with high cover of lichens and bare soil.

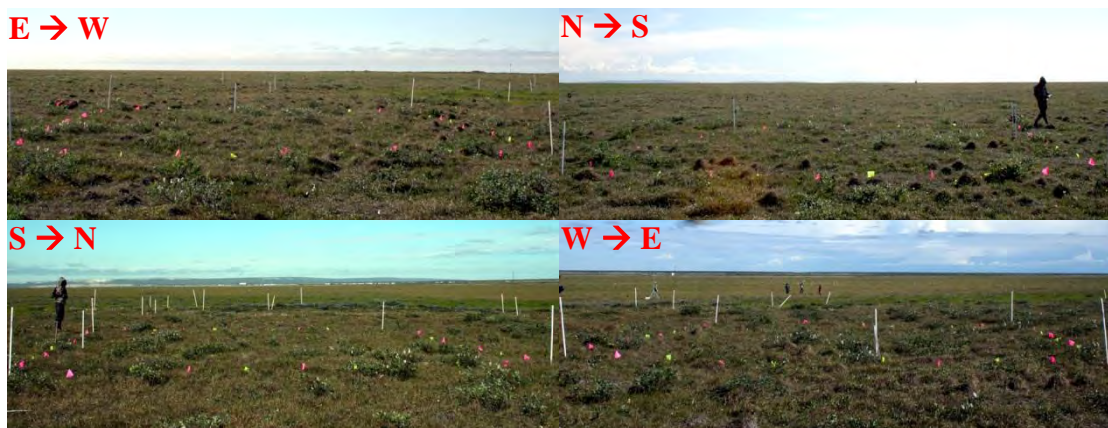


Figure C.4-3: Overview images of MNT tundra at the mesic Franklin Bluffs study location near the FBG4 site. Source: [Buchhorn and Schwieder, 2012]

III *Vegetation Description of the FBG4 Site*

The focus of the measurements at this goniometer site has been a horsetail patch. The 1 x 1 m plot is homogeneously covered with horsetail, but with forbs, mosses and lichens in the understory.



Figure C.4-4: Overview images of the FBG4 vegetation from cardinal directions.



Figure C.4-5: Nadir image of the FBG4 vegetation (horsetail).

IV *Overview of the Spectro-Goniometer Measurements*

Table C.4-1: Overview of the spectro-goniometer measurements at the FBG4 study site.

Name	Day	Starting Time	Duration	SAA	SZA	Sky
FBG4_01	2012-07-15	14:03:38	17 min	183°	48°	clear
FBG4_02	2012-07-15	15:32:07	17 min	211°	50°	clear
FBG4_03	2012-07-15	18:11:59	17 min	254°	60°	clear

Table C.4-2: Spectro-directional data of the FBG4_01 spectro-goniometer measurement.

Viewing Geometry (Viewing Zenith Angle Viewing Azimuth Angle)	Viewing Geometry (Viewing Zenith Angle Viewing Azimuth Angle)																			
	0j0	5180	5202.5	5225	5j0	522.5	545	590	5135	5157.5	10180	10190	10202.5	10225	10j270	10j315	10j337.5	10j350		
FBG4_01 (SA = 48°, SAA = 183°)	0.0176	0.0199	0.0201	0.0176	0.0169	0.0188	0.0193	0.0161	0.0150	0.0173	0.0202	0.0220	0.0210	0.0209	0.0200	0.0186	0.0165	0.0152		
HCRF EnMAP blue (479 nm)	0.0473	0.0496	0.0482	0.0462	0.0423	0.0505	0.0507	0.0445	0.0388	0.0437	0.0513	0.0534	0.0538	0.0522	0.0472	0.0501	0.0419	0.0462		
HCRF EnMAP green (549 nm)	0.0287	0.0325	0.0326	0.0281	0.0292	0.0284	0.0292	0.0244	0.0244	0.0300	0.0352	0.0336	0.0332	0.0329	0.0293	0.0257	0.0285	0.0226		
HCRF EnMAP rot (672 nm)	0.3358	0.3104	0.3192	0.3178	0.2988	0.3276	0.3386	0.3151	0.2746	0.2882	0.3263	0.3456	0.3389	0.3351	0.3076	0.3251	0.2914	0.3468		
ANIF EnMAP NIR (864 nm)	1.0000	1.2176	1.2209	1.0497	1.0136	1.0503	1.0930	0.9874	0.9424	0.8279	0.9118	1.1223	1.3151	1.2588	1.2323	1.2428	1.0968	1.0107		
ANIF EnMAP rot (672 nm)	1.0000	0.9243	0.9505	0.9464	0.8809	0.9756	1.0082	0.9382	0.8176	0.8583	0.9717	1.0292	0.9846	1.0092	0.9978	0.9159	0.8678	1.0373		
ANIF EnMAP NIR (864 nm)	0.8798	0.7923	0.7398	0.8431	0.7803	0.8661	0.8401	0.9030	0.7897	0.9690	1.0047	0.8667	0.7643	0.8253	0.8779	0.8011	0.8753	0.8669		
Rel. Blue Absorption Depth	4.1562	3.0210	3.1577	3.7265	3.5180	3.8164	3.8331	3.9070	3.4796	4.2559	4.4464	3.6920	3.2401	3.2882	2.9895	3.6419	3.8908	4.3395		
Rel. Red Absorption Depth	0.8525	0.8102	0.8145	0.8378	0.8322	0.8421	0.8411	0.8454	0.8319	0.8574	0.8610	0.8403	0.8078	0.8194	0.8210	0.8050	0.8346	0.8379		
NDVI (EnMAP)	1.0000	0.9484	0.9584	0.9843	0.9795	0.9813	0.9826	0.9932	0.9793	0.9925	0.9944	0.9757	0.9464	0.9578	0.9624	0.9481	0.9748	0.9833		
Nadir Norm. NDV (AVHRR)	1.0000	0.9492	0.9575	0.9836	0.9787	0.9821	0.9825	0.9926	0.9779	0.9947	0.9974	0.9769	0.9475	0.9587	0.9627	0.9473	0.9756	0.9829		
Nadir Norm. NDV (MODIS)	1.0000	0.9503	0.9553	0.9827	0.9761	0.9878	0.9866	0.9916	0.9758	1.0057	1.0099	0.9856	0.9475	0.9611	0.9630	0.9443	0.9789	0.9828		
Nadir Norm. NDV (EnMAP)																				

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Viewing Geometry (Viewing Zenith Angle Viewing Azimuth Angle)	Viewing Geometry (Viewing Zenith Angle Viewing Azimuth Angle)																			
	10j0	10j10	10j22.5	10j45	10j90	10j135	10j157.5	10j170	20j180	20j190	20j202.5	20j225	20j270	20j315	20j337.5	20j350	20j0	20j10	20j22.5	
FBG4_01 (SA = 48°, SAA = 183°)	0.0162	0.0158	0.0150	0.0154	0.0169	0.0206	0.0234	0.0242	0.0249	0.0266	0.0216	0.0218	0.0157	0.0143	0.0146	0.0158	0.0144	0.0149	0.0150	
HCRF EnMAP blue (479 nm)	0.0452	0.0446	0.0404	0.0472	0.0522	0.0546	0.0596	0.0588	0.0646	0.0700	0.0540	0.0584	0.0463	0.0468	0.0547	0.0550	0.0513	0.0539	0.0537	
HCRF EnMAP green (549 nm)	0.0259	0.0251	0.0241	0.0226	0.0228	0.0306	0.0372	0.0405	0.0373	0.0390	0.0340	0.0346	0.0237	0.0212	0.0198	0.0230	0.0208	0.0217	0.0226	
HCRF EnMAP rot (672 nm)	0.3153	0.3063	0.2799	0.3115	0.3270	0.3466	0.3551	0.3411	0.3618	0.3858	0.3171	0.3651	0.3102	0.3228	0.3823	0.3678	0.3587	0.3649	0.3610	
HCRF EnMAP NIR (864 nm)	0.9681	0.9407	0.8997	0.8446	0.8529	1.1431	1.3925	1.5133	1.3972	1.4571	1.2711	1.2934	0.8854	0.7943	0.7410	0.8610	0.7775	0.8112	0.8466	
ANIF EnMAP rot (672 nm)	0.9398	0.9093	0.8334	0.9276	0.9738	1.0321	1.0575	1.0158	1.1487	1.1477	1.2411	1.0573	0.9238	0.9612	1.1383	1.0951	1.0681	1.0749	1.0866	
ANIF EnMAP NIR (864 nm)	0.9117	0.9297	0.8711	1.0411	1.0586	0.8656	0.8237	0.7655	0.8482	0.8651	0.7971	0.8759	0.9859	1.1163	1.3112	1.1983	1.2368	1.2641	1.2430	
Rel. Blue Absorption Depth	4.0154	3.9939	3.7399	4.5968	4.7607	3.6416	3.0730	2.6813	3.0946	3.2052	2.9680	3.3529	4.3411	5.0765	6.6453	5.4644	5.8946	5.7641	5.3711	
Rel. Red Absorption Depth	0.8481	0.8478	0.8417	0.8648	0.8696	0.8380	0.8102	0.7880	0.8129	0.8166	0.8064	0.8225	0.8582	0.8766	0.9015	0.8822	0.8905	0.8878	0.8820	
NDVI (EnMAP)	0.9945	0.9884	0.9857	1.0009	1.0007	0.9734	0.9443	0.9206	0.9380	0.9390	0.9377	0.9566	0.9880	1.0173	1.0417	1.0185	1.0310	1.0254	1.0191	
Nadir Norm. NDV (AVHRR)	0.9943	0.9901	0.9854	1.0032	1.0044	0.9747	0.9466	0.9225	0.9414	0.9429	0.9384	0.9575	0.9991	1.0186	1.0438	1.0211	1.0329	1.0280	1.0219	
Nadir Norm. NDV (MODIS)	0.9948	0.9945	0.9873	1.0144	1.0201	0.9829	0.9504	0.9243	0.9535	0.9578	0.9459	0.9648	1.0067	1.0282	1.0574	1.0348	1.0445	1.0414	1.0346	
Nadir Norm. NDV (EnMAP)																				

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Viewing Geometry (Viewing Zenith Angle Viewing Azimuth Angle)	Viewing Geometry (Viewing Zenith Angle Viewing Azimuth Angle)																			
	20j135	20j157.5	20j170	30j180	30j190	30j202.5	30j225	30j270	30j315	30j337.5	30j350	30j0	30j10	30j22.5	30j45	30j90	30j135	30j157.5	30j170	
FBG4_01 (SA = 48°, SAA = 183°)	0.0215	0.0237	0.0244	0.0332	0.0319	0.0297	0.0189	0.0166	0.0144	0.0141	0.0136	0.0138	0.0144	0.0164	0.0168	0.0174	0.0234	0.0314	0.0319	
HCRF EnMAP blue (479 nm)	0.0604	0.0600	0.0616	0.0853	0.0892	0.0810	0.0570	0.0554	0.0540	0.0587	0.0537	0.0548	0.0577	0.0668	0.0634	0.0626	0.0710	0.0842	0.0798	
HCRF EnMAP green (549 nm)	0.0309	0.0347	0.0359	0.0500	0.0441	0.0439	0.0278	0.0217	0.0209	0.0194	0.0185	0.0200	0.0204	0.0238	0.0221	0.0232	0.0320	0.0454	0.0480	
HCRF EnMAP rot (672 nm)	0.3632	0.3440	0.3551	0.4311	0.4597	0.4148	0.3580	0.3710	0.3612	0.3913	0.3654	0.3610	0.3680	0.3969	0.3896	0.3685	0.3878	0.4350	0.4217	
HCRF EnMAP NIR (864 nm)	1.1551	1.2996	1.3432	1.8715	1.6509	1.6414	1.0407	0.8134	0.7827	0.7242	0.6911	0.7493	0.7625	0.8918	0.8280	0.8696	1.1956	1.6999	1.7953	
ANIF EnMAP rot (672 nm)	1.0814	1.0243	1.0573	1.2838	1.3698	1.2351	1.0659	1.1048	1.0757	1.1651	1.0880	1.0751	1.0957	1.1820	1.1602	1.0973	1.1548	1.2955	1.2557	
ANIF EnMAP NIR (864 nm)	0.9359	0.8149	0.8097	0.8372	0.9417	0.9117	1.0224	1.2381	1.3100	1.4775	1.3843	1.3919	1.4142	1.4441	1.4305	1.2780	1.0425	0.8878	0.8031	
Rel. Blue Absorption Depth	3.8178	3.1318	3.1843	2.7227	3.4125	3.0554	4.2891	5.8617	5.8572	6.9720	6.8169	6.1510	6.1877	5.7690	6.0442	3.9069	3.0246	2.7858	2.7858	
Rel. Red Absorption Depth	0.8433	0.8165	0.8163	0.7921	0.8248	0.8067	0.8558	0.8893	0.8905	0.9057	0.9037	0.8949	0.8950	0.8867	0.8925	0.8813	0.8477	0.8109	0.7956	
NDVI (EnMAP)	0.9721	0.9417	0.9453	0.9075	0.9383	0.9235	0.9879	1.0264	1.0251	1.0374	1.0391	1.0282	1.0247	1.0093	1.0184	1.0020	0.9821	0.9255	0.9155	
Nadir Norm. NDV (AVHRR)	0.9750	0.9444	0.9477	0.9126	0.9446	0.9290	0.9907	1.0294	1.0282	1.0414	1.0425	1.0321	1.0293	1.0155	1.0239	1.0085	0.9682	0.9313	0.9195	
Nadir Norm. NDV (MODIS)	0.9891	0.9578	0.9575	0.9291	0.9675	0.9485	1.0038	1.0431	1.0445	1.0624	1.0601	1.0497	1.0498	1.0401	1.0469	1.0338	0.9944	0.9511	0.9333	
Nadir Norm. NDV (EnMAP)																				

Table C.4-3: Spectro-directional data of the FBG4_02 spectro-goniometer measurement.

FBG4_02 (SZA = 50°; SAA = 211°)		Viewing Geometry (Viewing Zenith Angle Viewing Azimuth Angle)																				
		0j0	5j180	5j202.5	5j225	5j270	5j315	5j337.5	5j0	5j22.5	5j45	5j90	5j135	5j157.5	10j180	10j190	10j202.5	10j225	10j270	10j315	10j337.5	10j350
HCRF EnMAP blue (479 nm)	0.0140	0.0170	0.0161	0.0162	0.0192	0.0182	0.0137	0.0128	0.0136	0.0128	0.0137	0.0128	0.0136	0.0128	0.0167	0.0158	0.0166	0.0178	0.0186	0.0119	0.0106	0.0117
HCRF EnMAP green (549 nm)	0.0392	0.0433	0.0435	0.0424	0.0485	0.0394	0.0320	0.0343	0.0401	0.0408	0.0408	0.0428	0.0471	0.0394	0.0441	0.0443	0.0443	0.0475	0.0499	0.0380	0.0322	0.0327
HCRF EnMAP rot (672 nm)	0.0209	0.0273	0.0244	0.0241	0.0286	0.0181	0.0170	0.0206	0.0194	0.0184	0.0274	0.0184	0.0274	0.0285	0.0233	0.0265	0.0265	0.0300	0.0316	0.0154	0.0154	0.0179
HCRF EnMAP NIR (864 nm)	0.2668	0.2761	0.3014	0.2868	0.3067	0.3048	0.2438	0.2468	0.2703	0.2889	0.3070	0.2947	0.3059	0.2560	0.3042	0.3057	0.3030	0.3030	0.3163	0.3025	0.2402	0.2426
ANIF EnMAP rot (672 nm)	1.0000	1.3069	1.1666	1.1541	1.4188	0.8671	0.8163	0.9847	0.9271	0.8367	0.8789	1.3141	1.3650	1.2587	1.1153	1.1847	1.2692	1.3732	0.7864	0.7359	0.8549	0.8549
ANIF EnMAP NIR (864 nm)	1.0000	0.9627	1.0506	0.9998	1.0691	1.0628	0.8499	0.8603	0.9422	1.0073	1.0774	1.0274	1.0666	0.8625	1.0604	1.0659	1.0565	1.1098	1.0545	0.8375	0.8459	0.8459
Rel. Blue Absorption Depth	0.9174	0.8152	0.8734	0.8412	0.7969	1.0234	0.9231	0.7693	0.9792	1.0912	0.7077	0.8093	0.8133	0.7239	0.9182	0.8591	0.8645	0.8674	1.0796	1.0118	0.8123	0.8123
Rel. Red Absorption Depth	4.5877	3.2571	4.1114	3.9007	3.3630	5.7109	4.7012	3.9612	4.7114	5.9922	5.6963	3.4871	3.4724	3.0772	4.3145	4.1054	3.7700	3.6547	6.3038	5.1865	4.4921	4.4921
NDVI (EnMAP)	0.8643	0.8201	0.8504	0.8450	0.8238	0.8879	0.8693	0.8462	0.8663	0.8860	0.8872	0.8296	0.8295	0.8138	0.8578	0.8503	0.8392	0.8347	0.8970	0.8797	0.8629	0.8629
Nadir Norm. NDVI (AVHRR)	1.0000	0.9465	0.9837	0.9757	0.9513	1.0276	1.0076	0.9807	0.9942	1.0181	1.0187	0.9594	0.9598	0.9421	0.9887	0.9638	0.9626	1.0372	1.0130	0.9967	0.9967	0.9967
Nadir Norm. NDVI (MODIS)	1.0000	0.9470	0.9832	0.9758	0.9516	1.0266	1.0067	0.9795	0.9955	1.0193	1.0192	0.9592	0.9600	0.9412	0.9893	0.9632	0.9653	1.0363	1.0130	0.9959	0.9959	0.9959
Nadir Norm. NDVI (EnMAP)	1.0000	0.9489	0.9840	0.9777	0.9532	1.0273	1.0058	0.9790	1.0024	1.0251	1.0265	0.9599	0.9598	0.9416	0.9924	0.9838	0.9709	0.9658	1.0379	1.0179	0.9984	0.9984

(cont.)

FBG4_02 (SZA = 50°; SAA = 211°)		Viewing Geometry (Viewing Zenith Angle Viewing Azimuth Angle)																				
		10j0	10j10	10j22.5	10j45	10j90	10j135	10j157.5	10j170	20j180	20j190	20j202.5	20j225	20j270	20j315	20j337.5	20j350	20j0	20j10	20j22.5	20j45	20j90
HCRF EnMAP blue (479 nm)	0.0119	0.0121	0.0128	0.0132	0.0141	0.0141	0.0193	0.0168	0.0171	0.0226	0.0185	0.0179	0.0178	0.0155	0.0114	0.0115	0.0129	0.0118	0.0123	0.0122	0.0146	0.0144
HCRF EnMAP green (549 nm)	0.0337	0.0352	0.0405	0.0411	0.0475	0.0520	0.0441	0.0411	0.0600	0.0490	0.0468	0.0476	0.0525	0.0436	0.0437	0.0487	0.0485	0.0485	0.0483	0.0473	0.0512	0.0456
HCRF EnMAP rot (672 nm)	0.0175	0.0179	0.0173	0.0183	0.0185	0.0300	0.0254	0.0274	0.0331	0.0278	0.0258	0.0253	0.0222	0.0152	0.0159	0.0183	0.0161	0.0161	0.0174	0.0167	0.0195	0.0195
HCRF EnMAP NIR (864 nm)	0.2405	0.2500	0.2830	0.2886	0.3271	0.3249	0.3020	0.2687	0.3193	0.3033	0.3043	0.2995	0.3459	0.3210	0.2899	0.3161	0.3152	0.3140	0.3125	0.3269	0.3124	0.3124
ANIF EnMAP rot (672 nm)	0.8401	0.8583	0.8296	0.8775	0.8837	1.4379	1.2170	1.3122	1.5637	1.3302	1.2378	1.2122	1.0608	0.7292	0.7627	0.8771	0.7714	0.8834	0.8334	0.7984	0.9321	0.9360
ANIF EnMAP NIR (864 nm)	0.8393	0.8716	0.9866	1.0061	1.1405	1.1328	1.0528	0.9368	1.1132	1.0574	1.0608	1.0443	1.2059	1.1190	1.0108	1.1021	1.0991	1.0896	1.1397	1.0891	1.1397	1.0891
Rel. Blue Absorption Depth	0.9213	0.9750	1.0784	1.0513	1.1737	0.8895	0.8452	0.7522	0.8729	0.8624	0.8360	0.8619	1.1718	1.3419	1.3302	1.3324	1.4581	1.3895	1.3710	1.2256	1.0839	1.0839
Rel. Red Absorption Depth	4.5272	4.6948	5.2633	5.3519	6.0744	3.5477	3.8726	3.1326	3.0690	3.5195	3.8799	3.9533	5.2555	7.3079	6.1976	5.9356	6.7763	6.1939	6.4155	5.7942	5.4400	5.4400
NDVI (EnMAP)	0.8640	0.8662	0.8946	0.8806	0.8932	0.8508	0.8448	0.8149	0.8123	0.8322	0.8434	0.8442	0.8796	0.9094	0.8959	0.8905	0.9028	0.8950	0.8950	0.8876	0.8876	0.8876
Nadir Norm. NDVI (AVHRR)	0.9937	0.9964	1.0145	1.0126	1.0204	0.9543	0.9769	0.9449	0.9198	0.9543	0.9708	0.9687	1.0029	1.0403	1.0176	1.0107	1.0205	1.0138	1.0185	1.0097	1.0104	1.0104
Nadir Norm. NDVI (MODIS)	0.9937	0.9966	1.0159	1.0138	1.0223	0.9559	0.9767	0.9447	0.9239	0.9556	0.9718	0.9702	1.0055	1.0416	1.0208	1.0142	1.0245	1.0178	1.0225	1.0133	1.0122	1.0122
Nadir Norm. NDVI (EnMAP)	0.9987	1.0022	1.0235	1.0189	1.0335	0.9613	0.9774	0.9429	0.9399	0.9629	0.9759	0.9767	1.0178	1.0522	1.0365	1.0303	1.0445	1.0355	1.0398	1.0270	1.0270	1.0270

(cont.)

FBG4_02 (SZA = 50°; SAA = 211°)		Viewing Geometry (Viewing Zenith Angle Viewing Azimuth Angle)																				
		20j135	20j157.5	20j170	30j180	30j190	30j202.5	30j225	30j270	30j315	30j337.5	30j350	30j0	30j10	30j22.5	30j45	30j90	30j135	30j157.5	30j170		
HCRF EnMAP blue (479 nm)	0.0224	0.0216	0.0216	0.0270	0.0247	0.0204	0.0215	0.0159	0.0123	0.0128	0.0136	0.0132	0.0132	0.0152	0.0134	0.0141	0.0154	0.0219	0.0250	0.0289	0.0289	0.0289
HCRF EnMAP green (549 nm)	0.0600	0.0593	0.0581	0.0716	0.0712	0.0567	0.0682	0.0528	0.0541	0.0554	0.0589	0.0617	0.0632	0.0586	0.0641	0.0554	0.0585	0.0585	0.0714	0.0800	0.0800	0.0800
HCRF EnMAP rot (672 nm)	0.0335	0.0303	0.0313	0.0396	0.0343	0.0289	0.0290	0.0229	0.0164	0.0178	0.0190	0.0179	0.0183	0.0183	0.0184	0.0208	0.0326	0.0326	0.0354	0.0410	0.0410	0.0410
HCRF EnMAP NIR (864 nm)	0.3682	0.3470	0.3143	0.3677	0.3626	0.3488	0.3856	0.3307	0.3668	0.3492	0.3647	0.3753	0.3637	0.3710	0.3920	0.3423	0.3385	0.3932	0.4006	0.4006	0.4006	0.4006
ANIF EnMAP rot (672 nm)	1.6052	1.4530	1.4989	1.8944	1.6449	1.3864	1.3899	1.0957	0.7873	0.8522	0.9106	0.8590	0.9514	0.8755	0.8824	0.9942	1.5606	1.5606	1.6962	1.9615	1.9615	1.9615
ANIF EnMAP NIR (864 nm)	1.2836	1.2099	1.0956	1.2819	1.2641	1.2160	1.3445	1.1530	1.2786	1.2174	1.2714	1.3084	1.3378	1.2934	1.3667	1.1935	1.1802	1.1802	1.3710	1.3967	1.3967	1.3967
Rel. Blue Absorption Depth	0.8731	0.9093	0.8906	0.8733	0.9785	0.9682	1.1016	1.1455	1.5547	1.5370	1.5359	1.6639	1.4935	1.5608	1.6403	1.2758	0.8758	0.8758	0.9638	0.9381	0.9381	0.9381
Rel. Red Absorption Depth	3.6852	3.7371	3.1861	2.9649	3.4241	4.0177	4.4669	4.9159	7.8351	6.8036	6.7221	7.2900	7.0741	7.4278	5.8563	3.9653	3.9653	3.6633	3.1575	3.1575	3.1575	3.1575
NDVI (EnMAP)	0.8331	0.8392	0.8189	0.8057	0.8269	0.8467	0.8600	0.8706	0.9142	0.9030	0.9009	0.9088	0.9015	0.9061	0.9102	0.8857	0.8244	0.8244	0.8348	0.8145	0.8145	0.8145
Nadir Norm. NDVI (AVHRR)	0.9593	0.9553	0.9262	0.9121	0.9255	0.9630	0.9680	0.9903	1.0365	1.0185	1.0143	1.0181	1.0130	1.0200	1.0208	0.9983	0.9413	0.9413	0.9455	0.9149	0.9149	0.9149
Nadir Norm. NDVI (MODIS)	0.9602	0.9580	0.9302	0.9167	0.9321	0.9667	0.9738	0.9937	1.0401	1.0236	1.0198	1.0247	1.0189	1.0252	1.0272	1.0043	0.9440	0.9440	0.9498	0.9206	0.9206	0.9206
Nadir Norm. NDVI (EnMAP)	0.9639	0.9710	0.9474	0.9323	0.9568	0.9797	0.9951	1.0073	1.0578	1.0448	1.0423	1.0515	1.0431	1.0484	1.0531	1.0247	0.9538	0.9538	0.9658	0.9424	0.9424	0.9424

Table C.4-4: Spectro-directional data of the FBG4_03 spectro-goniometer measurement.

FBG4_03 (SZA = 60°; SAA = 254°)	Viewing Geometry (Viewing Zenith Angle Viewing Azimuth Angle)																				
	0j0	5 180	5 202.5	5 225	5 270	5 315	5 337.5	5j0	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)	0.0090	0.0115	0.0100	0.0101	0.0090	0.0098	0.0106	0.0108	0.0102	0.0097	0.0097	0.0095	0.0097	0.0128	0.0119	0.0100	0.0109	0.0094	0.0096	0.0108	0.0118
HCRF EnMAP green (549 nm)	0.0302	0.0352	0.0270	0.0306	0.0309	0.0286	0.0342	0.0337	0.0400	0.0347	0.0297	0.0290	0.0303	0.0369	0.0362	0.0291	0.0347	0.0321	0.0326	0.0420	0.0412
HCRF EnMAP rot (672 nm)	0.0109	0.0148	0.0126	0.0129	0.0108	0.0137	0.0140	0.0147	0.0127	0.0125	0.0124	0.0124	0.0124	0.0164	0.0153	0.0124	0.0132	0.0115	0.0132	0.0139	0.0154
HCRF EnMAP NIR (864 nm)	0.2351	0.2448	0.2014	0.2171	0.2342	0.2252	0.2506	0.2456	0.2948	0.2631	0.2312	0.2172	0.2231	0.2675	0.2406	0.2103	0.2393	0.2528	0.2501	0.2912	0.2876
ANIF EnMAP rot (672 nm)	1.0000	1.3607	1.1613	1.1879	0.9876	1.2554	1.2855	1.3313	1.1623	1.1628	1.1509	1.1372	1.1382	1.5045	1.4026	1.1425	1.2690	1.0556	1.2085	1.2793	1.4119
ANIF EnMAP NIR (864 nm)	1.0000	1.0413	0.8567	0.9232	0.9961	0.9577	1.0660	1.0446	1.2537	1.1190	0.9836	0.9239	0.9490	1.1376	1.0235	0.8945	1.0179	1.0753	1.0639	1.2387	1.2231
Rel. Blue Absorption Depth	1.1390	1.0313	0.8585	1.0148	1.1741	0.9662	1.1394	1.0510	1.3681	1.1703	0.9810	1.0271	1.0522	1.0560	1.0246	0.9562	1.0877	1.1621	1.1643	1.3670	1.2134
Rel. Red Absorption Depth	7.3934	5.6894	5.2584	5.6791	7.4252	5.4771	6.0634	5.6895	8.0557	7.0986	6.2882	6.0216	6.0987	5.5795	5.2887	5.5980	5.8945	7.4873	6.3099	7.2448	6.3306
NDVI (EnMAP)	0.9114	0.8658	0.8818	0.8875	0.9122	0.8855	0.8942	0.8895	0.9176	0.9081	0.8971	0.8921	0.8947	0.8845	0.8806	0.8883	0.8908	0.9130	0.9000	0.9087	0.8985
Nadir Norm. NDVI (AVHRR)	1.0000	0.9698	0.9722	0.9723	0.9965	0.9771	0.9772	0.9739	1.0011	0.9933	0.9893	0.9795	0.9822	0.9651	0.9593	0.9744	0.9736	1.0024	0.9867	0.9869	0.9784
Nadir Norm. NDVI (MODIS)	1.0000	0.9713	0.9718	0.9731	0.9974	0.9759	0.9788	0.9745	1.0022	0.9936	0.9887	0.9797	0.9823	0.9674	0.9621	0.9750	0.9748	1.0021	0.9868	0.9896	0.9805
Nadir Norm. NDVI (EnMAP)	1.0000	0.9719	0.9675	0.9737	1.0008	0.9715	0.9811	0.9748	1.0068	0.9843	0.9788	0.9816	0.9705	0.9662	0.9746	0.9773	1.0017	0.9875	0.9875	0.9970	0.9858

(cont.)

FBG4_03 (SZA = 60°; SAA = 254°)	Viewing Geometry (Viewing Zenith Angle Viewing Azimuth Angle)																				
	10j0	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	20j0	20 10	20 22.5	20 45	20 90
HCRF EnMAP blue (479 nm)	0.0108	0.0111	0.0101	0.0107	0.0101	0.0085	0.0105	0.0102	0.0144	0.0140	0.0134	0.0129	0.0121	0.0100	0.0112	0.0116	0.0120	0.0116	0.0109	0.0102	0.0101
HCRF EnMAP green (549 nm)	0.0391	0.0408	0.0406	0.0412	0.0324	0.0230	0.0319	0.0327	0.0453	0.0458	0.0465	0.0470	0.0499	0.0440	0.0490	0.0541	0.0560	0.0534	0.0484	0.0413	0.0321
HCRF EnMAP rot (672 nm)	0.0140	0.0144	0.0125	0.0131	0.0132	0.0109	0.0135	0.0124	0.0181	0.0173	0.0163	0.0156	0.0144	0.0126	0.0142	0.0146	0.0148	0.0144	0.0136	0.0124	0.0127
HCRF EnMAP NIR (864 nm)	0.2857	0.2974	0.3066	0.2975	0.2448	0.1949	0.2242	0.2346	0.2690	0.2708	0.2805	0.2954	0.3348	0.2949	0.3172	0.3483	0.3571	0.3453	0.3226	0.2993	0.2335
ANIF EnMAP rot (672 nm)	1.2850	1.3191	1.1450	1.1983	1.2130	1.0033	1.2363	1.1403	1.6617	1.5893	1.4993	1.4340	1.3257	1.1551	1.3077	1.3401	1.3611	1.3237	1.2528	1.1365	1.1668
ANIF EnMAP NIR (864 nm)	1.2153	1.2648	1.3041	1.2652	1.0412	0.7864	0.9538	0.9978	1.1442	1.1516	1.1931	1.2563	1.4240	1.2541	1.3490	1.4812	1.5187	1.4689	1.3722	1.2730	0.9934
Rel. Blue Absorption Depth	1.2516	1.2880	1.4265	1.3629	1.0856	0.8644	1.0214	1.0963	1.0822	1.1364	1.2220	1.2904	1.4718	1.5786	1.5627	1.6594	1.6710	1.6563	1.5809	1.4324	1.0764
Rel. Red Absorption Depth	6.9751	7.0867	8.4952	7.8407	6.3085	5.5853	5.6208	6.3974	5.0075	5.2697	5.8153	6.4665	8.1010	8.0264	7.7071	8.3080	8.4794	8.3872	8.2298	8.3915	6.1839
NDVI (EnMAP)	0.9086	0.9078	0.9218	0.9159	0.8976	0.8884	0.8867	0.8994	0.8739	0.8798	0.8900	0.8995	0.9173	0.9181	0.9140	0.9195	0.9203	0.9198	0.9188	0.9206	0.8968
Nadir Norm. NDVI (AVHRR)	0.9891	0.9809	1.0071	0.9855	0.9859	0.9809	0.9700	0.9827	0.9409	0.9468	0.9571	0.9695	0.9824	0.9894	0.9828	0.9877	0.9875	0.9889	0.9904	1.0010	0.9811
Nadir Norm. NDVI (MODIS)	0.9905	0.9922	1.0079	0.9973	0.9861	0.9795	0.9711	0.9839	0.9457	0.9521	0.9623	0.9742	0.9957	0.9936	0.9874	0.9924	0.9924	0.9933	0.9942	1.0031	0.9819
Nadir Norm. NDVI (EnMAP)	0.9847	0.9860	1.0114	1.0048	0.9848	0.9747	0.9728	0.9868	0.9588	0.9653	0.9764	0.9869	1.0064	1.0074	1.0028	1.0089	1.0097	1.0092	1.0081	1.0100	0.9839

(cont.)

FBG4_03 (SZA = 60°; SAA = 254°)	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	30j0	30 10	30 122.5	30 45	30 90	30 135	30 157.5	30 170	30 22.5	30 45
HCRF EnMAP blue (479 nm)	0.0112	0.0117	0.0145	0.0188	0.0203	0.0186	0.0158	0.0133	0.0132	0.0124	0.0134	0.0136	0.0134	0.0122	0.0112	0.0118	0.0141	0.0164	0.0164	0.0197	0.0187
HCRF EnMAP green (549 nm)	0.0343	0.0358	0.0449	0.0594	0.0697	0.0682	0.0584	0.0581	0.0693	0.0618	0.0638	0.0672	0.0683	0.0576	0.0472	0.0447	0.0475	0.0543	0.0543	0.0610	0.0610
HCRF EnMAP rot (672 nm)	0.0142	0.0146	0.0179	0.0234	0.0251	0.0220	0.0196	0.0159	0.0166	0.0155	0.0167	0.0174	0.0173	0.0154	0.0139	0.0151	0.0169	0.0199	0.0199	0.0253	0.0253
HCRF EnMAP NIR (864 nm)	0.2277	0.2453	0.2798	0.3260	0.3644	0.3456	0.3632	0.4130	0.3806	0.3839	0.4057	0.4076	0.3643	0.3160	0.2892	0.2915	0.3068	0.3068	0.3299	0.3299	0.3299
ANIF EnMAP rot (672 nm)	1.2995	1.3363	1.6392	2.1502	2.3047	2.0172	1.8023	1.4623	1.5205	1.4220	1.5347	1.5996	1.5861	1.4173	1.2796	1.3829	1.5527	1.8301	1.8301	2.3194	2.3194
ANIF EnMAP NIR (864 nm)	0.9686	1.0435	1.1900	1.3868	1.5497	1.6077	1.4702	1.6300	1.7565	1.6186	1.6329	1.7254	1.7337	1.5497	1.3439	1.2303	1.2399	1.3049	1.4031	1.4031	1.4031
Rel. Blue Absorption Depth	1.0300	1.0395	1.0683	1.0990	1.2220	1.3203	1.3065	1.5655	1.8747	1.7765	1.6967	1.7641	1.8235	1.6906	1.4980	1.3386	1.1855	1.1608	1.0783	1.0783	1.0783
Rel. Red Absorption Depth	5.3376	5.6334	5.3551	4.6266	4.8951	5.8343	6.0441	4.8485	8.8032	8.6157	8.0243	8.2253	8.3129	8.2093	7.7965	6.5367	5.8031	5.1818	4.3250	4.3250	4.3250
NDVI (EnMAP)	0.8830	0.8880	0.8900	0.8660	0.8711	0.8901	0.8925	0.9202	0.9229	0.9218	0.9165	0.9176	0.9187	0.9155	0.9010	0.8903	0.8780	0.8780	0.8577	0.8577	0.8577
Nadir Norm. NDVI (AVHRR)	0.9592	0.9679	0.9516	0.9272	0.9242	0.9456	0.9599	0.9934	0.9810	0.9840	0.9765	0.9784	0.9764	0.9833	0.9865	0.9709	0.9584	0.9381	0.9172	0.9172	0.9172
Nadir Norm. NDVI (MODIS)	0.9614	0.9697	0.9557	0.9338	0.9322	0.9534	0.9656	0.9976	0.9884	0.9899	0.9827	0.9846	0.9830	0.9886	0.9903	0.9752	0.9630	0.9446	0.9240	0.9240	0.9240
Nadir Norm. NDVI (EnMAP)	0.9687	0.9743	0.9655	0.9501	0.9557	0.9766	0.9792	1.0096	1.0125	1.0113	1.0056	1.0068	1.0079	1.0080	1.0045	0.9885	0.9768	0.9633	0.9411	0.9411	0.9411

V Main Spectral Characteristics

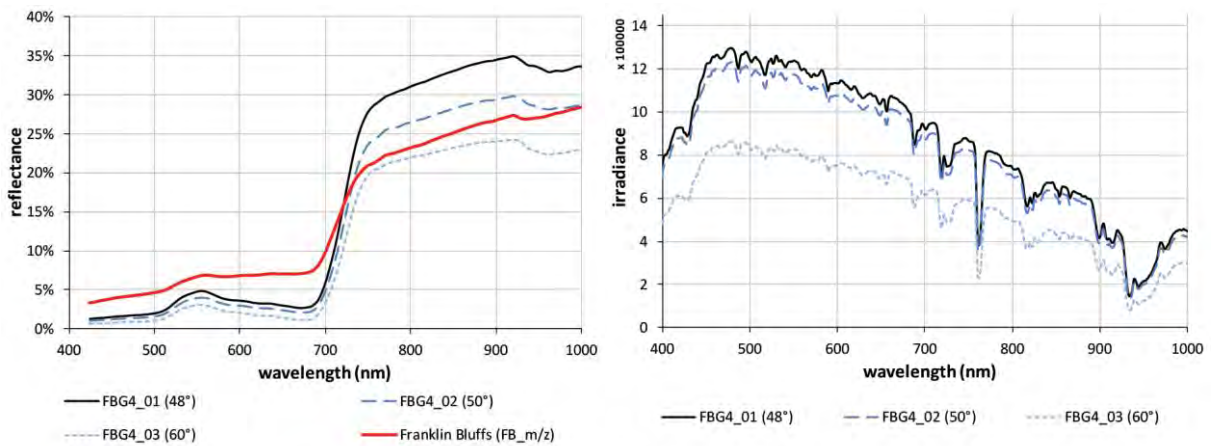


Figure C.4-6: Nadir reflectances and irradiance profiles of the FBG4 site at different sun zenith angles. Left: Comparison of the nadir reflectance signatures with the average zonal vegetation (MNT). Right: Comparison of the total irradiance profiles.

VI HCRF Visualization

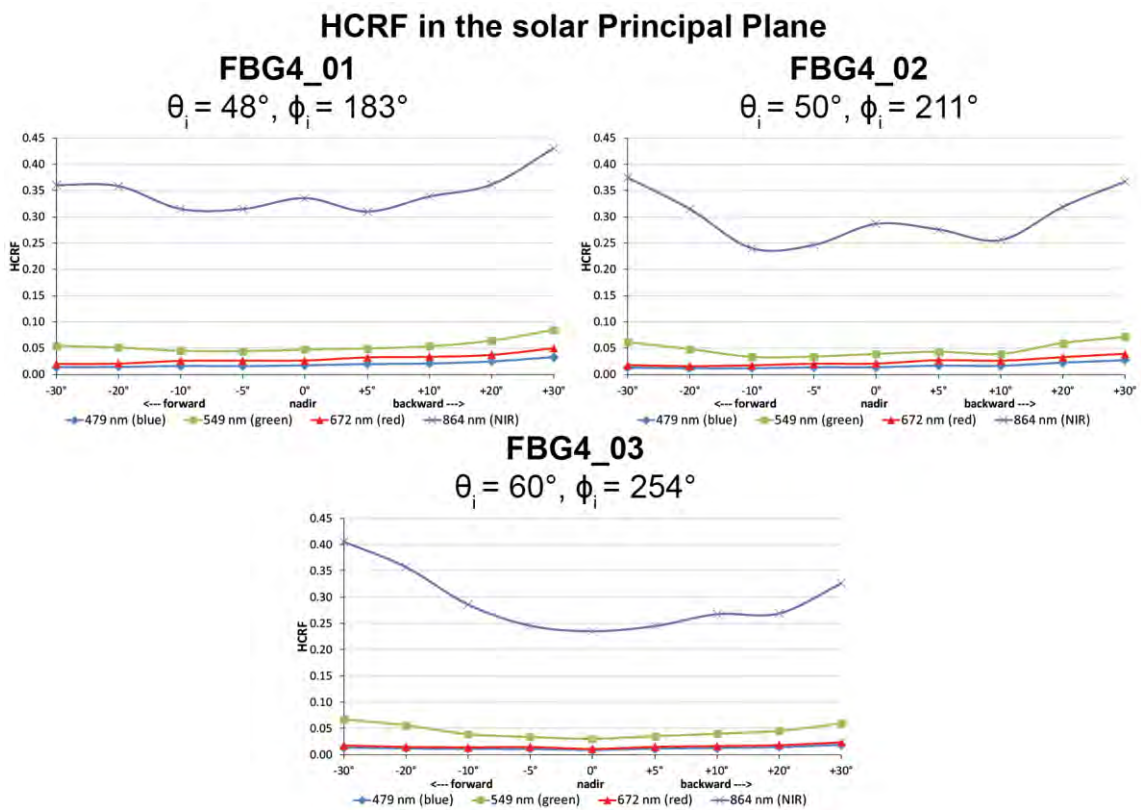


Figure C.4-7: Comparison of the HCRF values at 479 nm (blue), 549 nm (green), 672 nm (red), and 864 nm (NIR) in the solar principal plane of the FBG4 site at different sun zenith angles.

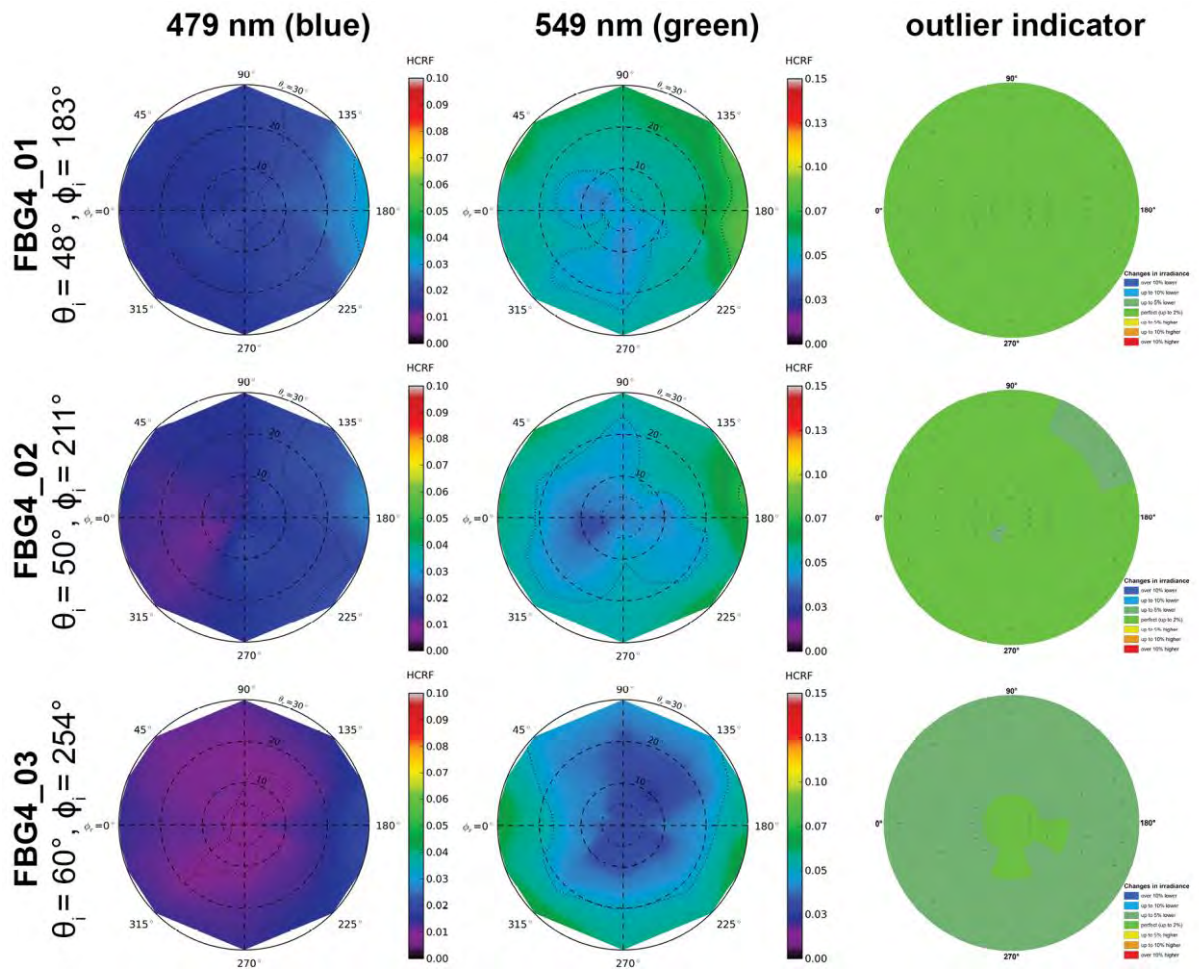


Figure C.4-8: HCRF visualization at 479 nm and 549 nm of the FBG4 site.

Changes in irradiance



Figure C.4-9: Legend of the outlier indicator graphics shown in Figure C.4-8, C.4-10, and C.4-13

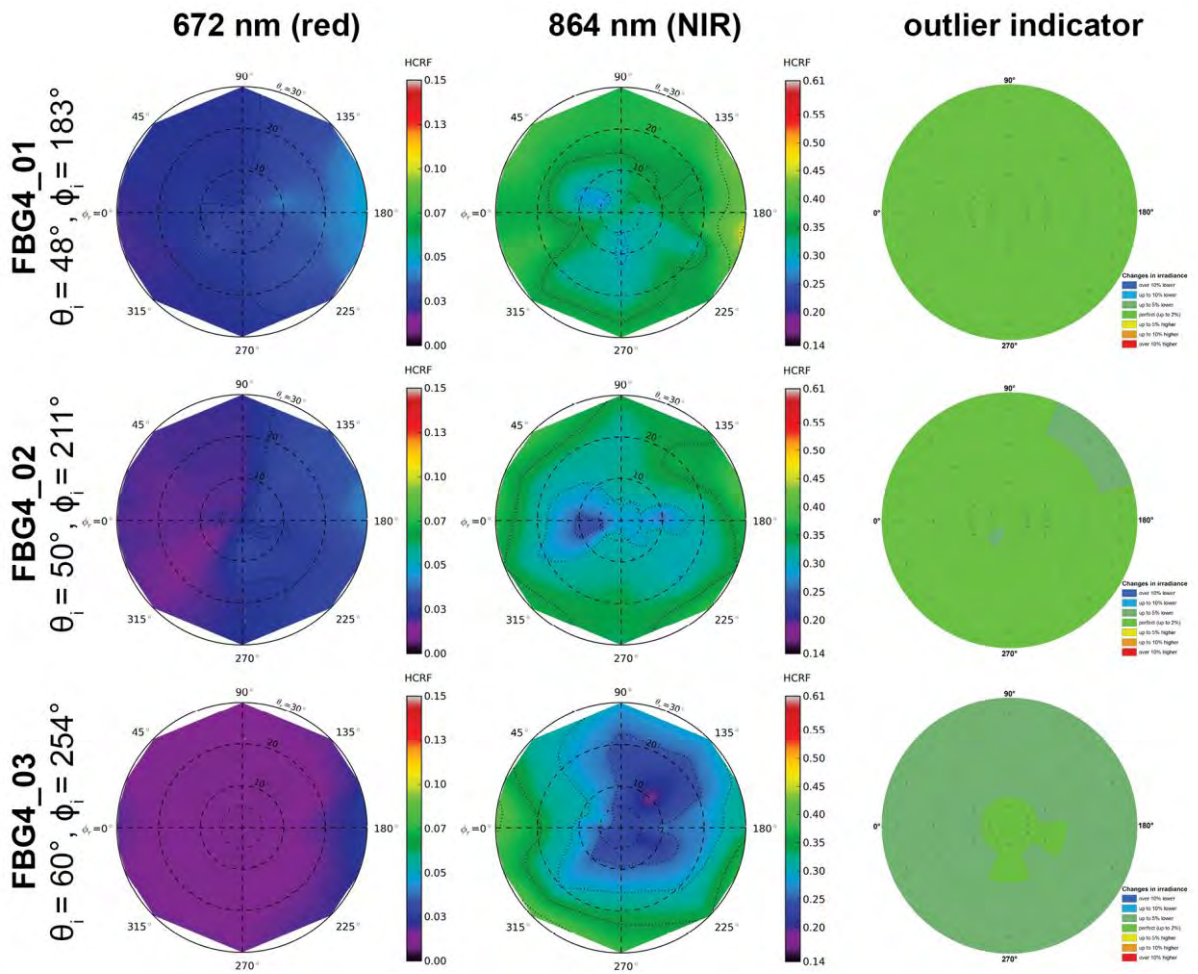


Figure C.4-10: HCRF visualization at 672 nm and 864 nm of the FBG4 site.

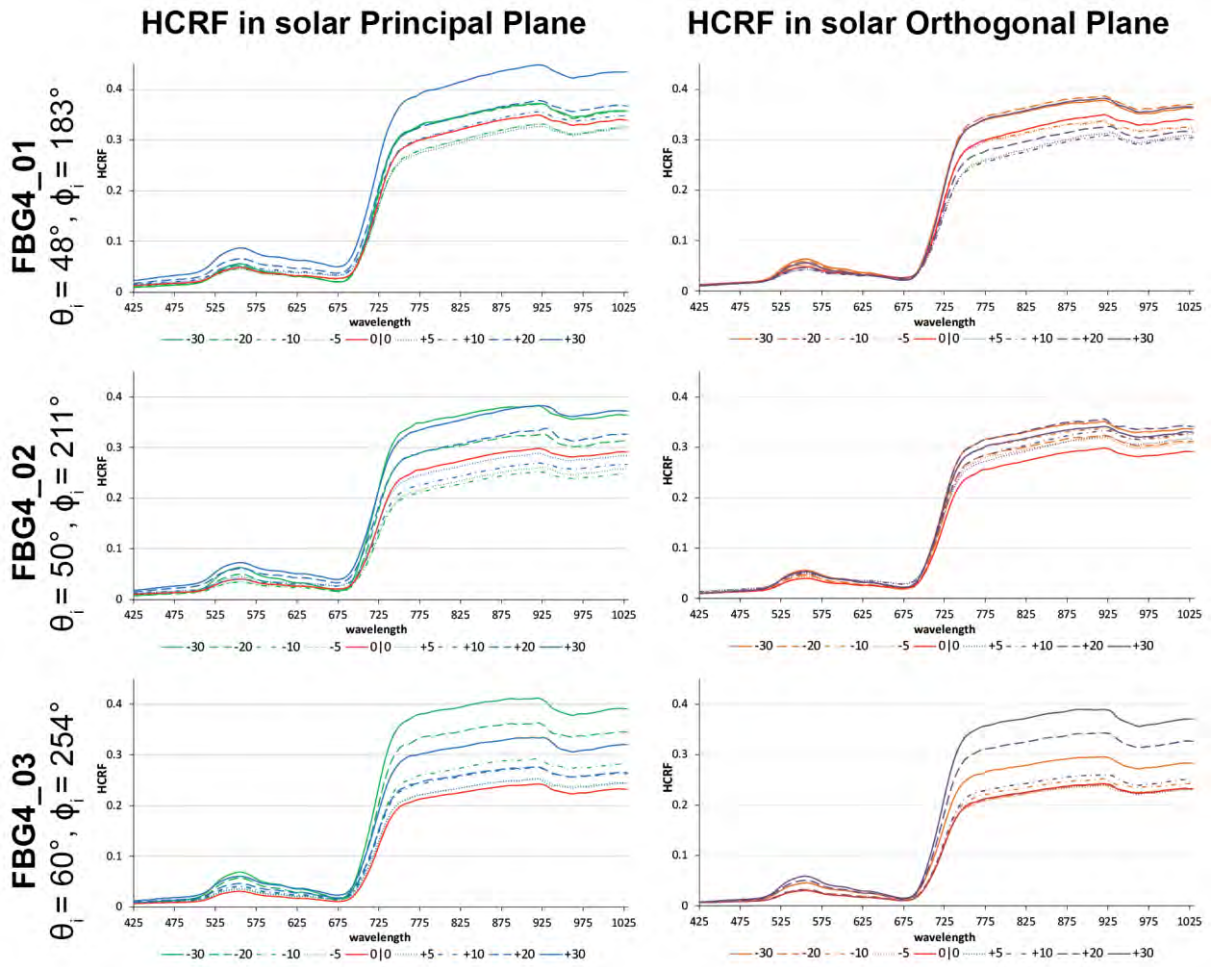


Figure C.4-11: HCRF visualization in principal & orthogonal plane of the FBG4 site.

VII ANIF Visualization

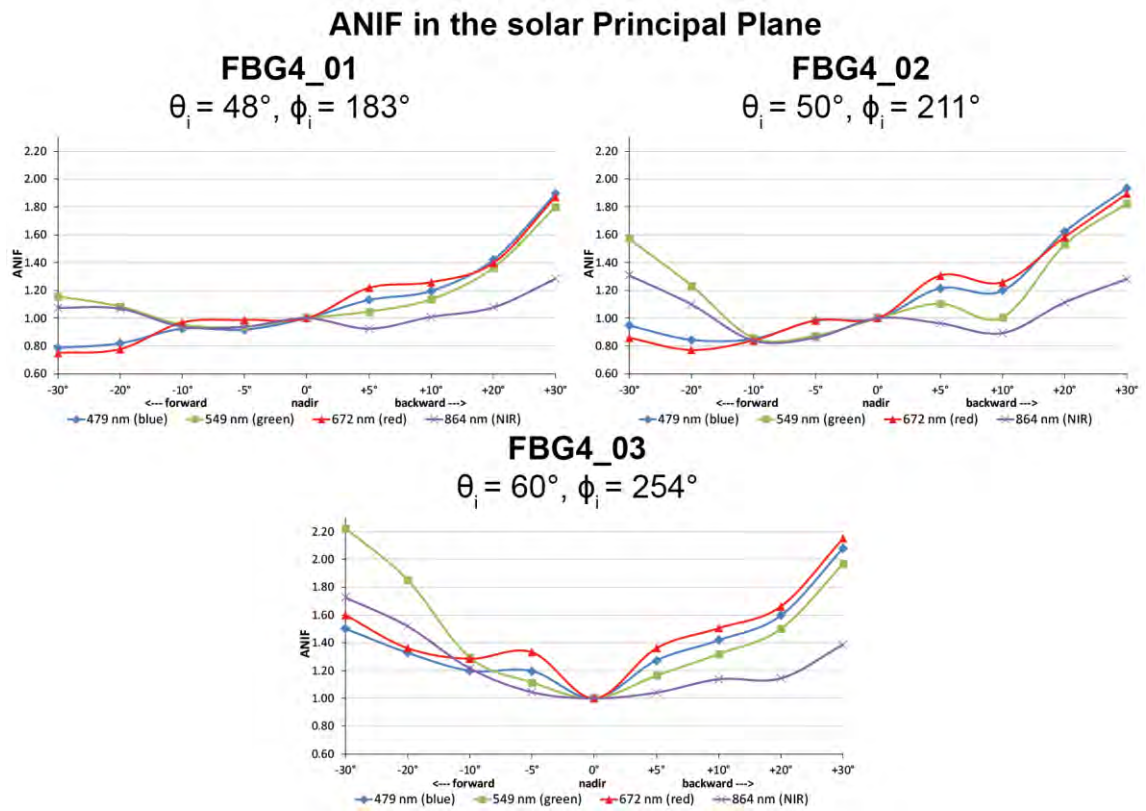


Figure C.4-12: Comparison of the ANIF values at 479 nm (blue), 549 nm (green), 672 nm (red), and 864 nm (NIR) in the solar principal plane of the FBG4 site at different sun zenith angles.

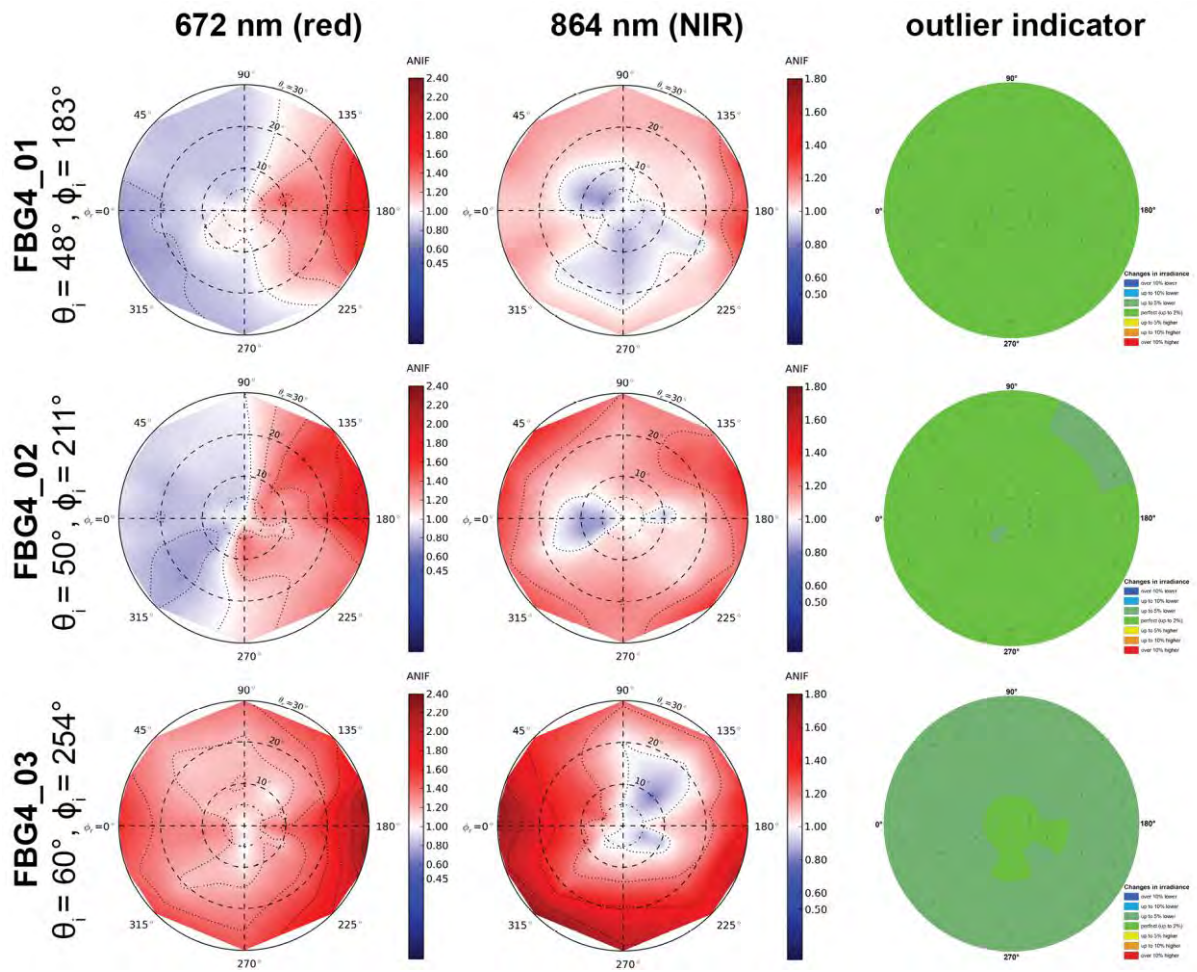


Figure C.4-13: ANIF visualization at 672 nm and 864 nm of the FBG4 site.

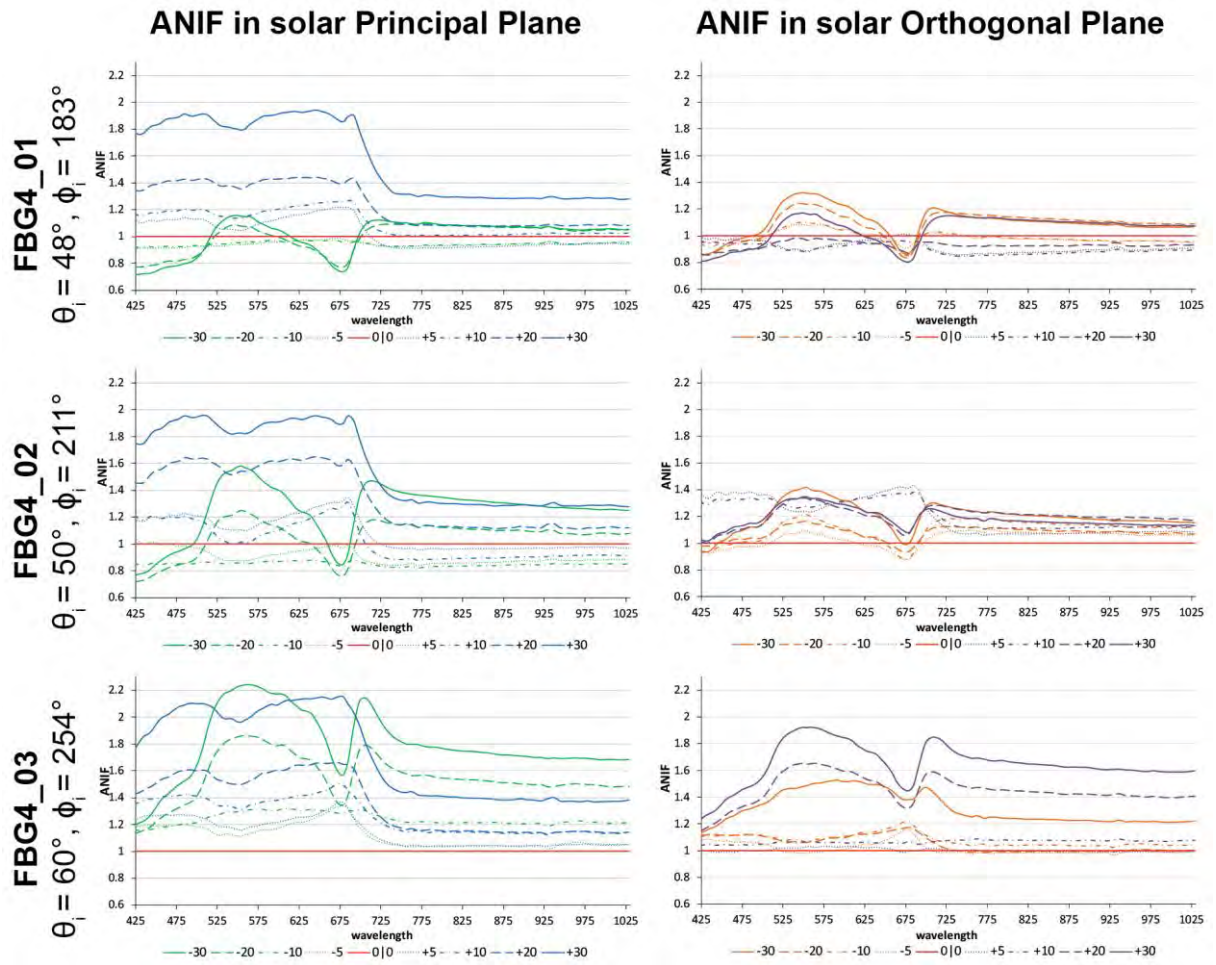


Figure C.4-14: ANIF visualization in principal & orthogonal plane of the FBG4 site.

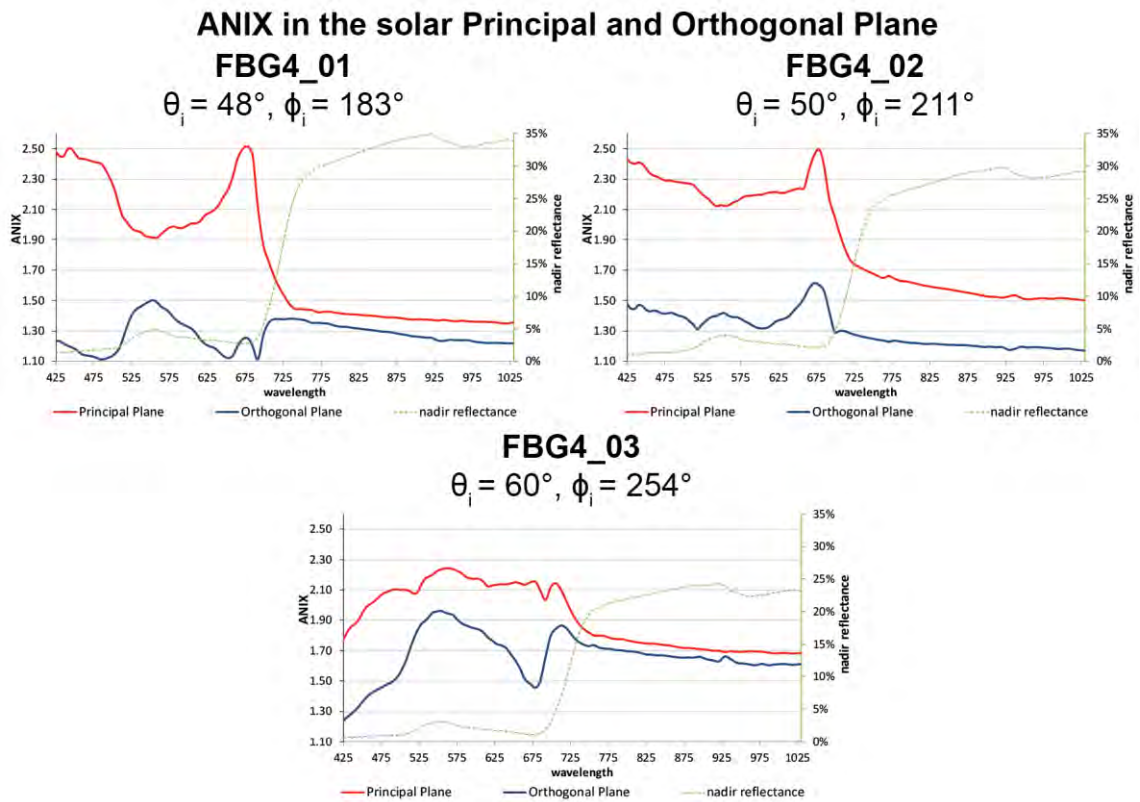
VIII *ANIX Visualization*

Figure C.4-15: Comparison of the ANIX in the solar principal and orthogonal plane with the nadir reflectance of the FBG4 site at different sun zenith angles.

IX NDVI and Relative Absorption Depth Visualization

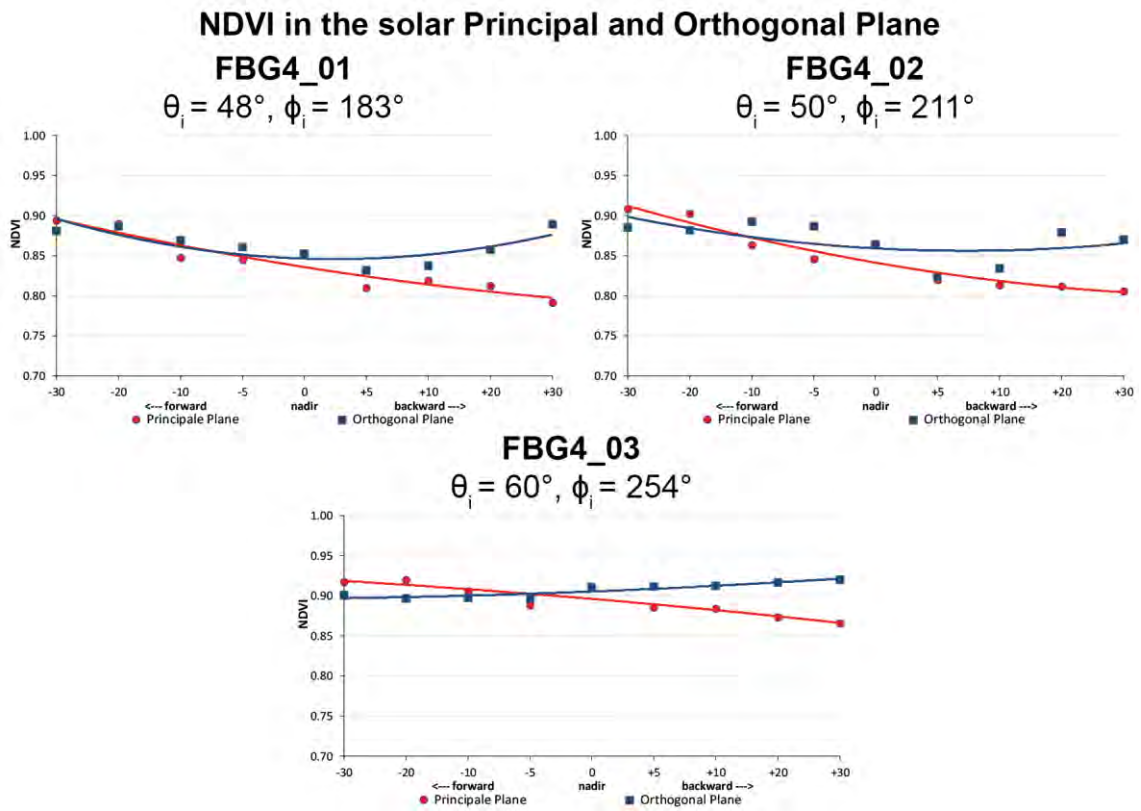


Figure C.4-16: Comparison of the NDVI in the solar principal and orthogonal plane of the FBG4 site at different sun zenith angles.

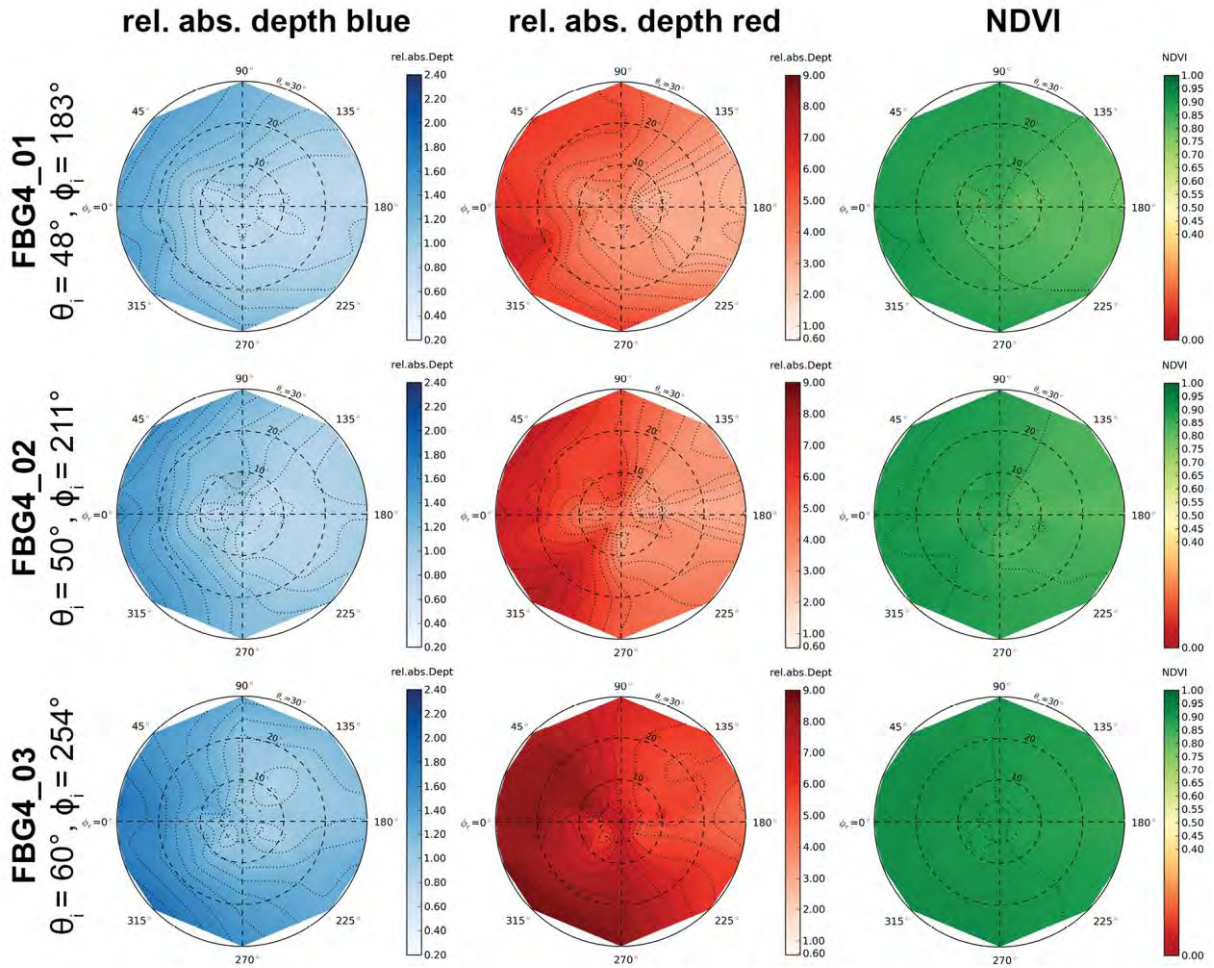


Figure C.4-17: Visualization of relative absorption depth & NDVI of the FBG4 site.

X NDVI Comparison of Different Sensors

Table C.4-5: 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

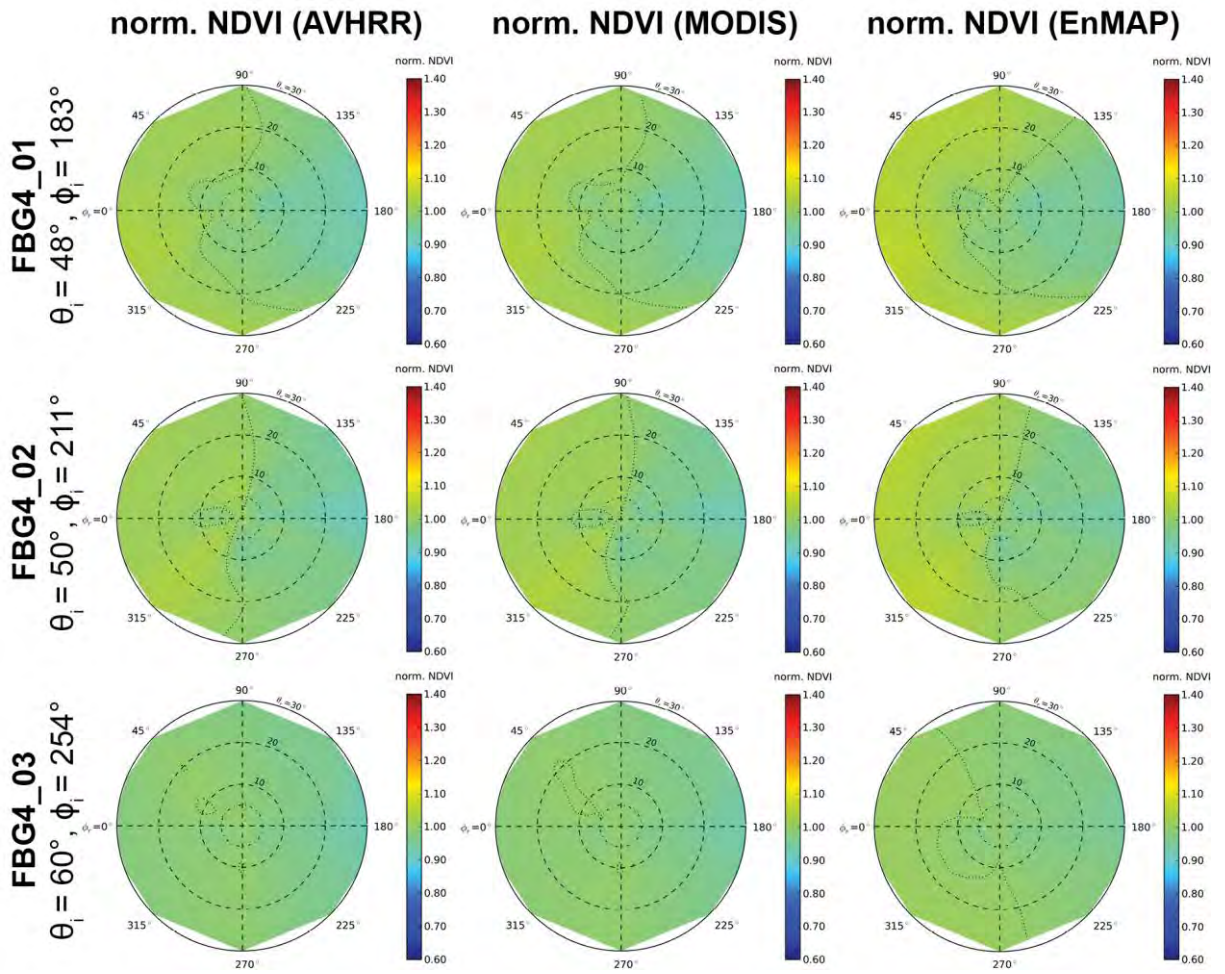


Figure C.4-18: Comparison of AVHRR, MODIS & EnMAP NDVI of the FBG4 site.