

C.7 Study site VDG1 (sedge, dwarf shrub, moss tundra)

I Location

Name	Location	Latitude	Longitude	Altitude
VDG1	Vaskiny Dachi, Yamal Peninsula, West Siberia, Russian Federation	70.275783°	68.89125°	45 m

Vaskiny Dachi is located southeast of the main Bovanenkova gas field in the central part of the Yamal Peninsula. Vaskiny Dachi is the name of a field camp established by Dr. Marina Leibman. The research sites are located in the watersheds of the Se-Yakha and Mordy-Ykha rivers. The Vaskiny Dachi-1 study site is on a gentle Terrace-IV hill-top, which is on a Kazantsevskaya coastal-marine plain (Terrace IV) at 40-45 m elevation and built of interbedding of clayey and sandy deposits with a considerable amount of organic matter dispersed in the section. [Walker *et al.*, 2009]

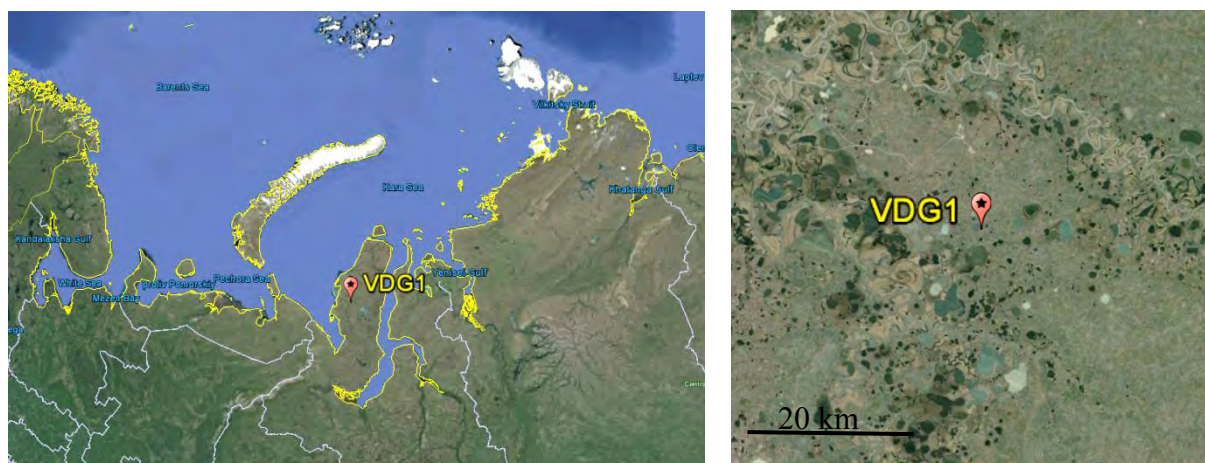


Figure C.7-1: Location of study site VDG1 in Yamal, Russia. *Source:* Google Earth, 2013



Figure C.7-2: Satellite image of the 100 x 100 m zonal grid at the Vaskiny Dachi study location where the VDG1 site is located. *Source:* Google Earth, 2013

II Main Vegetation Description

The soils are clay and the vegetation is heavily grazed sedge - dwarf shrub - moss tundra dominated by *Carex bigelowii*, *Vaccinium vitis-idaea*, *Salix glauca*, *Hylocomium splendens*, and *Aulacomnium turgidum*. The surfaces sometimes have windblown sands, but are mainly tussocky, hummocky or frost-boil tundra and peatland in the lower areas. [Walker *et al.*, 2009]



Figure C.7-3: Overview images of the grazed tundra at the mesic Vaskiny Dachi study location near the VDG1 site. Source: [Heim *et al.*, 2012]

III Vegetation Description of the VDG1 Site

The focus of the measurements at this goniometer site has been sedge – dwarf shrub - moss tundra. The 1x1 m plot is homogeneously covered with dwarf-shrub-moss tundra.



Figure C.7-4: Overview images of the VDG1 vegetation. Left: Photo in the visible wavelength range. Middle: Photo in the NIR wavelength range. Right: Vegetation height measurement with help of the card box approach. Source: [Heim *et al.*, 2012]



Figure C.7-5: Quasi-nadir image of the VDG1 vegetation (dwarf-shrub-moss tundra).

IV *Overview of the Spectro-Goniometer Measurements*

Table C.7-1: Overview of the spectro-goniometer measurements at the VDG1 study site.

Name	Day	Starting Time	Duration	SAA	SZA	Sky
VDG1_02	2011-08-12	13:20:18	40 min	180°	55°	cirrostratus

Table C.7-2: Spectro-directional data of the VDG1_02 spectro-goniometer measurement.

VDG1_02 (SZA = 55°; SAA = 180°)	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)	0.0210	0.0197	0.0189	0.0187	0.0180	0.0187	0.0261	0.0245	0.0251	0.0210	0.0187	0.0193	0.0154	0.0181	0.0208	0.0206	0.0176	0.0178	0.0201	0.0217	0.0237
HCRF EnMAP green (549 nm)	0.0445	0.0404	0.0387	0.0381	0.0326	0.0390	0.0540	0.0518	0.0499	0.0406	0.0343	0.0372	0.0338	0.0349	0.0440	0.0422	0.0385	0.0370	0.0401	0.0500	0.0512
HCRF EnMAP rot (672 nm)	0.0355	0.0348	0.0348	0.0327	0.0321	0.0348	0.0426	0.0418	0.0425	0.0361	0.0333	0.0344	0.0273	0.0304	0.0363	0.0312	0.0303	0.0311	0.0363	0.0363	0.0391
HCRF EnMAP NIR (864 nm)	0.2440	0.1907	0.1759	0.1815	0.1602	0.2023	0.2683	0.2710	0.2468	0.2091	0.1747	0.1816	0.1784	0.1635	0.2093	0.1980	0.1812	0.1785	0.1952	0.2766	0.2696
ANIF EnMAP rot (672 nm)	1.0000	0.9668	0.9803	0.9573	0.7937	0.9233	1.2001	1.1786	1.1988	1.0172	0.9382	0.9704	0.7686	0.8563	1.0289	0.9942	0.8791	0.8762	1.0250	1.0247	1.1029
ANIF EnMAP NIR (864 nm)	1.0000	0.7812	0.7209	0.7493	0.6563	0.8288	1.0995	1.1103	1.0112	0.8569	0.7160	0.7442	0.7312	0.6698	0.8577	0.8112	0.7425	0.7314	0.8000	1.1333	1.1048
Rel. Blue Absorption Depth	0.6082	0.5805	0.5784	0.5746	0.5785	0.5976	0.5921	0.6129	0.5546	0.5313	0.4924	0.5210	0.6329	0.5236	0.6152	0.5806	0.6444	0.6310	0.5688	0.6989	0.6347
Rel. Red Absorption Depth	2.1227	1.6801	1.4566	1.5355	1.6645	1.8361	1.9401	1.9637	1.7491	1.7322	1.5144	1.5551	1.9897	1.5476	1.7085	1.6652	1.7020	1.7126	1.5668	2.4282	2.1430
NDVI (EnMAP)	0.7463	0.6952	0.6701	0.6848	0.7011	0.7214	0.7262	0.7327	0.7061	0.7058	0.6801	0.6815	0.7350	0.6867	0.7032	0.6977	0.7065	0.7035	0.6861	0.7678	0.7467
Nadir Norm. NDVI (AVHRR)	1.0000	0.9345	0.9030	0.9237	0.9308	0.9621	0.9686	0.9761	0.9427	0.9525	0.9230	0.9223	0.9827	0.9227	0.9413	0.9310	0.9390	0.9377	0.9258	1.0202	0.9994
Nadir Norm. NDVI (MODIS)	1.0000	0.9381	0.9032	0.9226	0.9328	0.9627	0.9704	0.9772	0.9430	0.9517	0.9182	0.9190	0.9831	0.9269	0.9452	0.9348	0.9416	0.9365	0.9235	1.0229	1.0020
Nadir Norm. NDVI (EnMAP)	1.0000	0.9315	0.8979	0.9177	0.9395	0.9666	0.9731	0.9819	0.9462	0.9458	0.9114	0.9131	0.9849	0.9202	0.9422	0.9349	0.9466	0.9427	0.9194	1.0288	1.0055

(cont.)

VDG1_02 (SZA = 55°; SAA = 180°)	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)	0.0235	0.0246	0.0251	0.0199	0.0213	0.0197	0.0155	0.0174	0.0198	0.0204	0.0213	0.0220	0.0171	0.0178	0.0183	0.0175	0.0172	0.0178	0.0180	0.0198	0.0199
HCRF EnMAP green (549 nm)	0.0506	0.0518	0.0509	0.0410	0.0393	0.0397	0.0329	0.0355	0.0450	0.0445	0.0468	0.0486	0.0357	0.0375	0.0391	0.0364	0.0347	0.0384	0.0387	0.0414	0.0405
HCRF EnMAP rot (672 nm)	0.0377	0.0398	0.0404	0.0349	0.0366	0.0337	0.0272	0.0304	0.0347	0.0366	0.0396	0.0399	0.0293	0.0322	0.0307	0.0304	0.0300	0.0295	0.0291	0.0311	0.0326
HCRF EnMAP NIR (864 nm)	0.2650	0.2677	0.2593	0.2219	0.1976	0.1654	0.1671	0.2206	0.2105	0.2212	0.2194	0.1763	0.1878	0.2103	0.1956	0.1923	0.2185	0.2185	0.2132	0.2203	0.2092
ANIF EnMAP rot (672 nm)	1.0629	1.1231	1.1387	0.9856	1.0314	0.9515	0.7660	0.8580	0.9780	1.0321	1.1160	1.1249	0.8256	0.9095	0.8654	0.8562	0.8457	0.8329	0.8210	0.8769	0.8181
ANIF EnMAP NIR (864 nm)	1.0658	1.0970	1.0625	0.9093	0.8096	0.7962	0.6848	0.9039	0.8625	0.9066	0.8990	0.7225	0.7695	0.8619	0.8014	0.7882	0.8014	0.8329	0.8210	0.9027	0.8574
Rel. Blue Absorption Depth	0.6331	0.6027	0.5676	0.5904	0.4807	0.5644	0.6092	0.5693	0.6760	0.6358	0.6521	0.6202	0.5924	0.6097	0.6232	0.5831	0.5895	0.6182	0.6206	0.5934	0.5749
Rel. Red Absorption Depth	2.1891	2.0666	1.9586	1.9222	1.5878	1.7464	1.7881	1.6069	1.8983	1.6880	1.6634	1.6184	1.7955	1.7370	2.1066	1.9591	1.9214	2.2993	2.2444	2.1769	1.9478
NDVI (EnMAP)	0.7510	0.7410	0.7305	0.7279	0.6876	0.7041	0.7179	0.6926	0.7283	0.7038	0.6966	0.6923	0.7153	0.7069	0.7454	0.7313	0.7303	0.7618	0.7597	0.7526	0.7307
Nadir Norm. NDVI (AVHRR)	1.0014	0.9824	0.9791	0.9776	0.9299	0.9471	0.9640	0.9320	0.9654	0.9387	0.9359	0.9266	0.9541	0.9492	1.0005	0.9845	0.9895	1.0206	1.0145	1.0085	0.9769
Nadir Norm. NDVI (MODIS)	1.0033	0.9841	0.9797	0.9769	0.9281	0.9498	0.9653	0.9331	0.9682	0.9409	0.9374	0.9287	0.9555	0.9490	1.0007	0.9827	0.9875	1.0206	1.0174	1.0110	0.9796
Nadir Norm. NDVI (EnMAP)	1.0063	0.9829	0.9789	0.9753	0.9214	0.9435	0.9620	0.9281	0.9759	0.9431	0.9334	0.9277	0.9584	0.9472	0.9988	0.9799	0.9785	1.0208	1.0180	1.0085	0.9792

(cont.)

VDG1_02 (SZA = 55°; SAA = 180°)	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	30j180	30j190
HCRF EnMAP blue (479 nm)	0.0189	0.0201	0.0210	0.0266	0.0251	0.0256	0.0235	0.0215	0.0205	0.0163	0.0172	0.0172	0.0226	0.0227	0.0169	0.0189	0.0193	0.0248	0.0258	0.0258	0.0258
HCRF EnMAP green (549 nm)	0.0395	0.0444	0.0446	0.0566	0.0562	0.0544	0.0523	0.0440	0.0423	0.0331	0.0335	0.0367	0.0451	0.0450	0.0337	0.0352	0.0418	0.0535	0.0578	0.0578	0.0578
HCRF EnMAP rot (672 nm)	0.0337	0.0349	0.0379	0.0482	0.0449	0.0456	0.0420	0.0386	0.0345	0.0277	0.0296	0.0289	0.0380	0.0364	0.0274	0.0316	0.0343	0.0423	0.0438	0.0438	0.0438
HCRF EnMAP NIR (864 nm)	0.1845	0.2051	0.2048	0.2530	0.2509	0.2457	0.2541	0.2110	0.1933	0.1773	0.2068	0.2372	0.2378	0.2376	0.1889	0.1758	0.1968	0.2402	0.2607	0.2607	0.2607
ANIF EnMAP rot (672 nm)	0.9514	0.9840	1.0681	1.3599	1.2674	1.2865	1.1847	1.0878	0.9740	0.7817	0.8343	0.8138	1.0707	1.0263	0.7719	0.8918	0.9684	1.1934	1.2344	1.2344	1.2344
ANIF EnMAP NIR (864 nm)	0.7559	0.8405	0.8392	1.0369	1.0281	1.0067	1.0411	0.8887	0.8646	0.7922	0.7267	0.8473	0.9719	0.9744	0.7740	0.7203	0.8066	0.9842	1.0682	1.0682	1.0682
Rel. Blue Absorption Depth	0.5961	0.6517	0.6106	0.6200	0.6506	0.6230	0.6678	0.5804	0.5858	0.5687	0.5236	0.6118	0.6880	0.5397	0.5479	0.4882	0.6406	0.8322	0.6706	0.6706	0.6706
Rel. Red Absorption Depth	1.5866	1.7546	1.5834	1.5665	1.6834	1.6066	1.8338	1.6887	1.8523	2.1754	1.7802	2.2069	1.8682	2.0009	2.0895	1.6192	1.6822	1.6986	1.8246	1.8246	1.8246
NDVI (EnMAP)	0.6908	0.7092	0.6879	0.6799	0.6962	0.6968	0.7162	0.6980	0.7187	0.7492	0.7141	0.7551	0.7240	0.7346	0.7469	0.6951	0.7029	0.7004	0.7125	0.7125	0.7125
Nadir Norm. NDVI (AVHRR)	0.9308	0.9448	0.9145	0.9088	0.9302	0.9149	0.9494	0.9374	0.9634	1.0152	0.9642	1.0160	0.9762	0.9872	1.0076	0.9400	0.9434	0.9327	0.9442	0.9442	0.9442
Nadir Norm. NDVI (MODIS)	0.9307	0.9480	0.9181	0.9109	0.9335	0.9185	0.9538	0.9383	0.9671	1.0128	0.9632	1.0155	0.9761	0.9890	1.0077	0.9417	0.9471	0.9367	0.9480	0.9480	0.9480
Nadir Norm. NDVI (EnMAP)	0.9257	0.9504	0.9217	0.9111	0.9329	0.9203	0.9597	0.9354	0.9630	1.0039	0.9569	1.0118	0.9702	0.9843	1.0008	0.9314	0.9419	0.9366	0.9547	0.9547	0.9547

V Main Spectral Characteristics

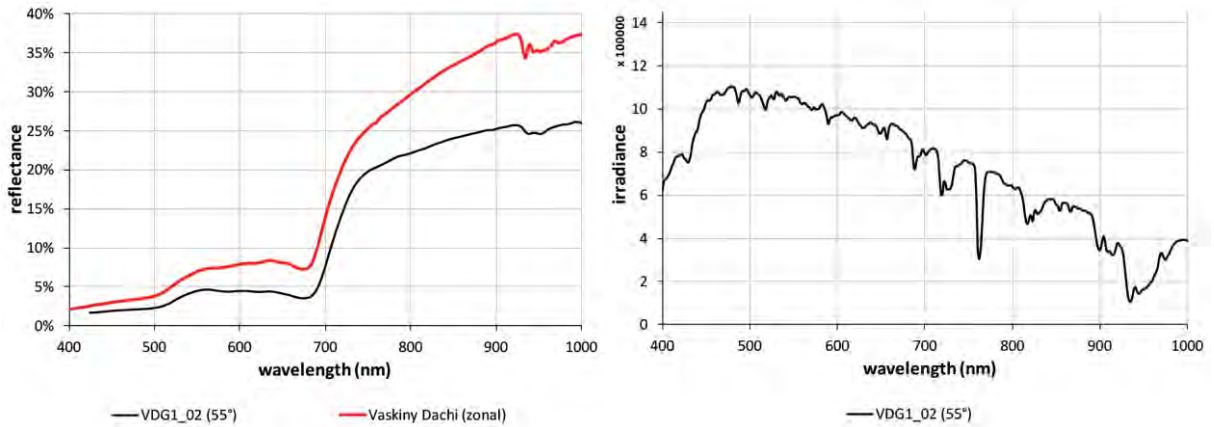


Figure C.7-6: Nadir reflectances and irradiance profiles of the VDG1 site. Left: Comparison of the nadir reflectance signatures with the average zonal vegetation. Right: Comparison of the total irradiance profiles.

VI HCRF Visualization

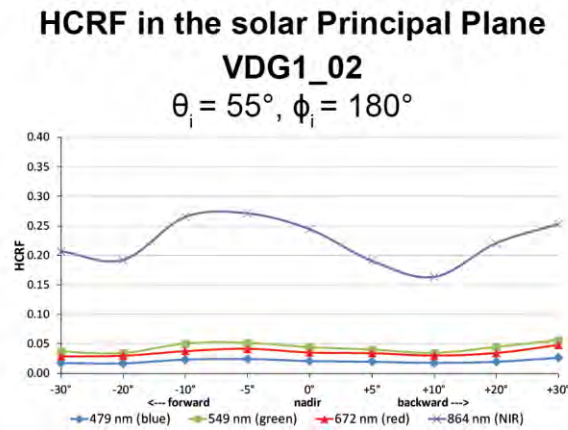


Figure C.7-7: Comparison of the HCRF values at 479 nm (blue), 549 nm (green), 672 nm (red), and 864 nm (NIR) in the solar principal plane of the VDG1 site.

Changes in irradiance



Figure C.7-8: Legend of the outlier indicator graphics shown in Figure C.7-9, C.7-10, and C.7-13

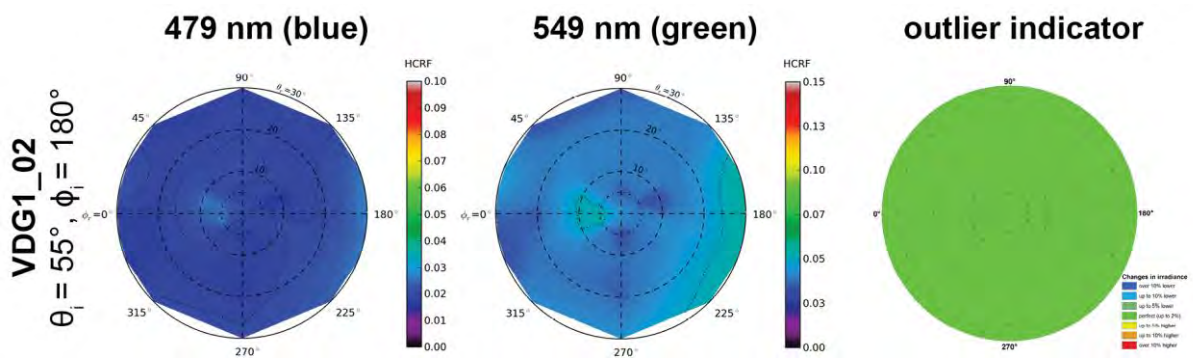


Figure C.7-9: HCRF visualization at 479 nm and 549 nm of the VDG1 site.

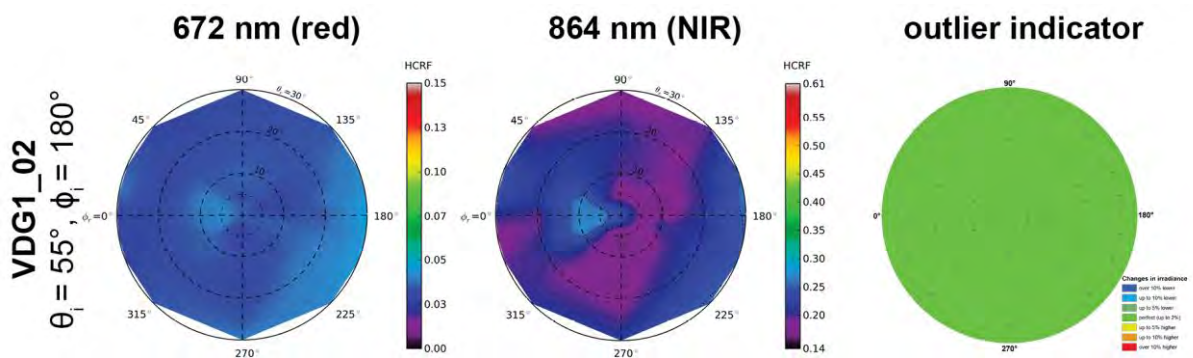


Figure C.7-10: HCRF visualization at 672 nm and 864 nm of the VDG1 site.

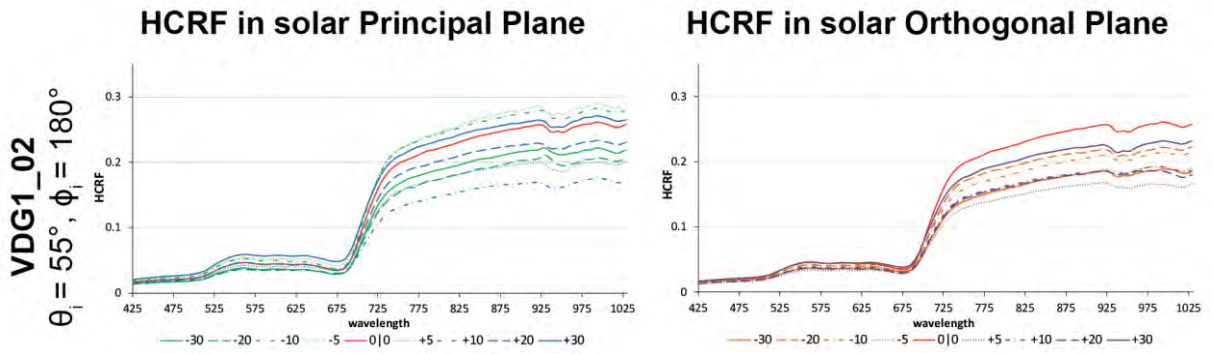


Figure C.7-11: HCRF visualization in principal & orthogonal plane of the VDG1 site.

VII ANIF Visualization

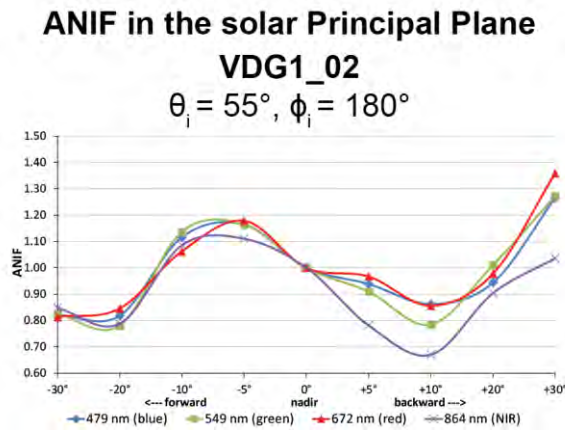


Figure C.7-12: Comparison of the ANIF values at 479 nm (blue), 549 nm (green), 672 nm (red), and 864 nm (NIR) in the solar principal plane of the VDG1 site.

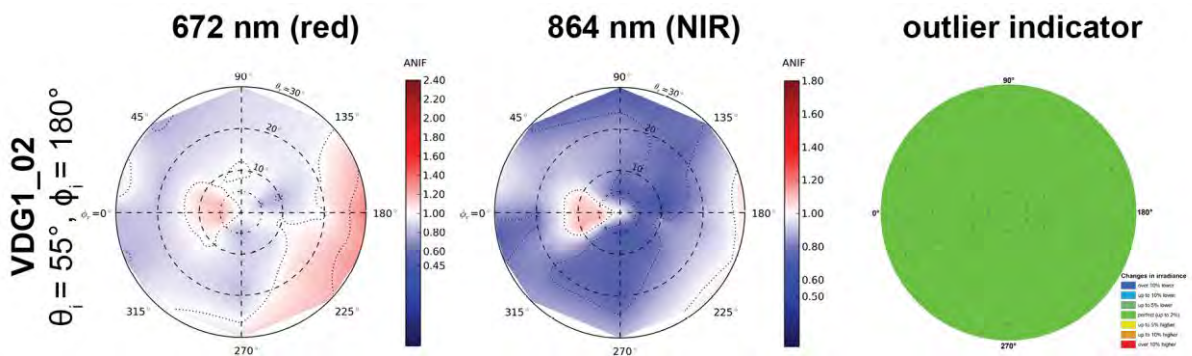


Figure C.7-13: ANIF visualization at 672 nm and 864 nm of the VDG1 site.

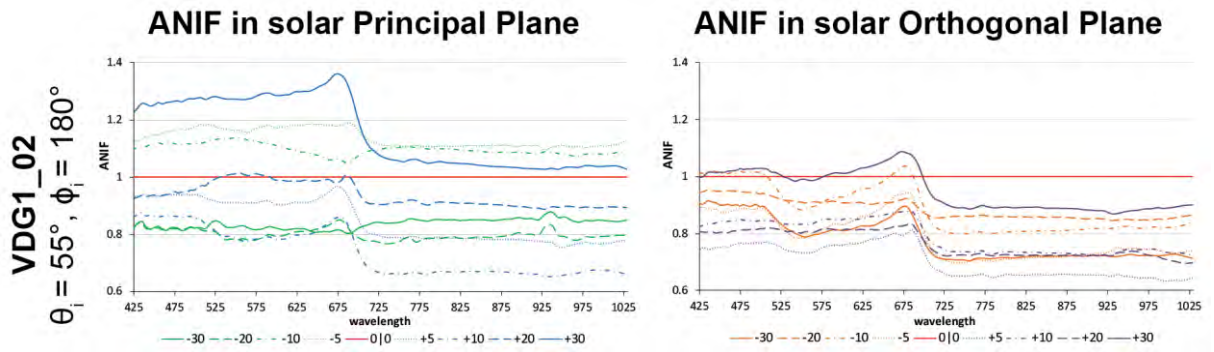


Figure C.7-14: ANIF visualization in principal & orthogonal plane of the VDG1 site.

VIII ANIX Visualization

ANIX in the solar Principal and Orthogonal Plane

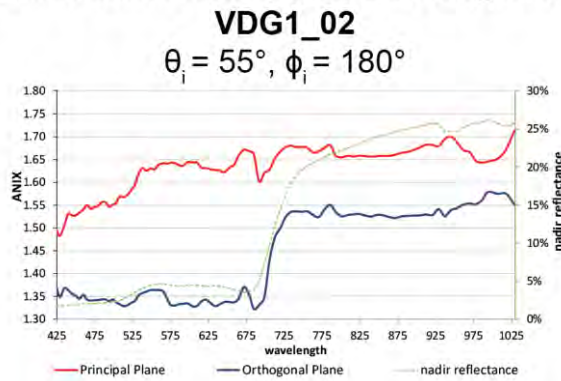


Figure C.7-15: Comparison of the ANIX in the solar principal and orthogonal plane with the nadir reflectance of the VDG1 site.

IX NDVI and Relative Absorption Depth Visualization

NDVI in the solar Principal and Orthogonal Plane

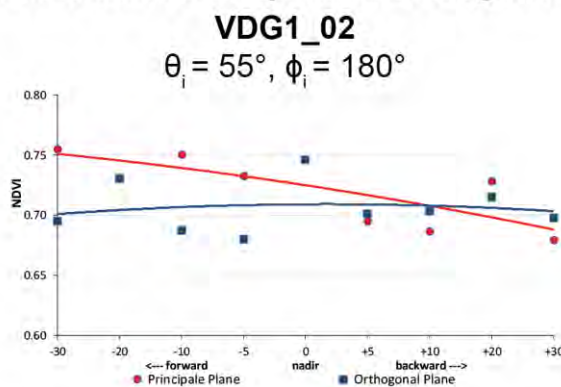


Figure C.7-16: Comparison of the NDVI in the solar principal and orthogonal plane of the VDG1 site.

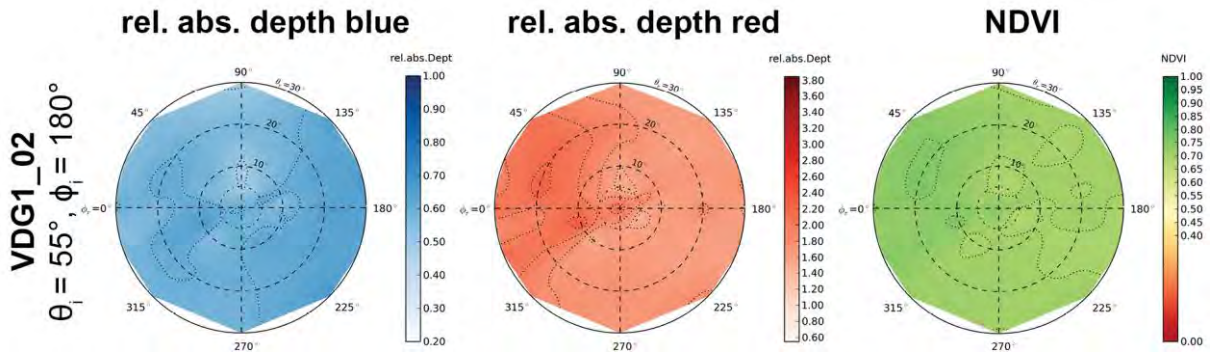


Figure C.7-17: Visualization of relative absorption depth & NDVI of the VDG1 site.

X NDVI Comparison of Different Sensors

Table C.7-3: 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	630	100
		NIR: band 2	865	275
NDVI _{MODIS} [broadband]	MODIS	red: band 1	645	50
		NIR: band 2	859	35
NDVI _{EnMAP} [narrowband]	EnMAP	red: band 47	672	6.5
		NIR: band 73	864	8

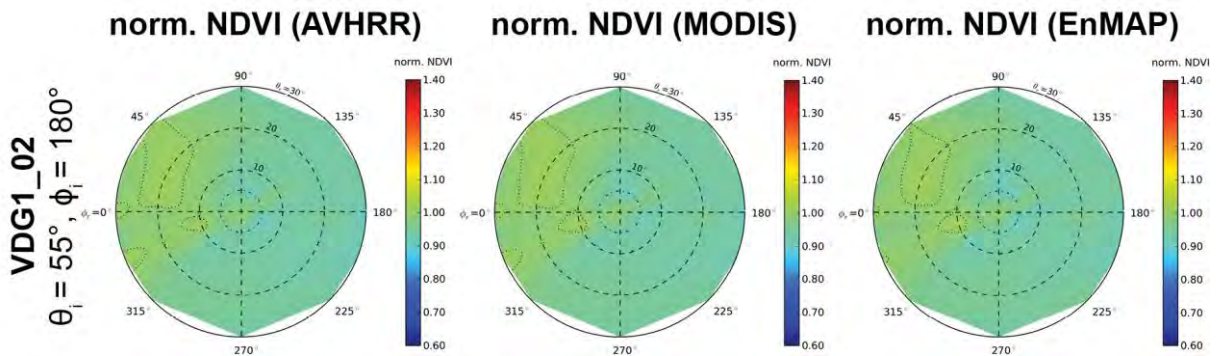


Figure C.7-18: Comparison of AVHRR, MODIS & EnMAP NDVI of the VDG1 site.