



Experiences with Radiance in Daylighting Design, Part VIII

**18th International Radiance Conference
August 21-22, New York City**

**Zack Rogers, P.E., IESNA, LEED AP BD+C
Daylighting Innovations, LLC**



**DAYLIGHTING
INNOVATIONS**



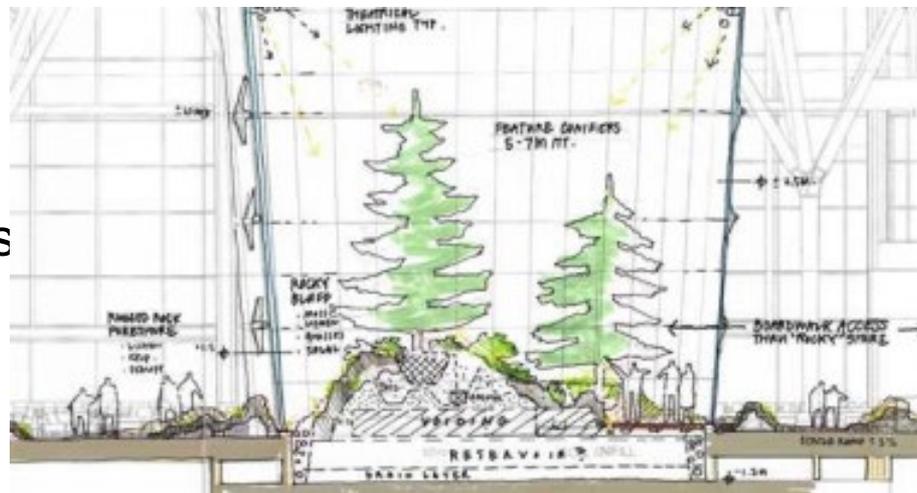
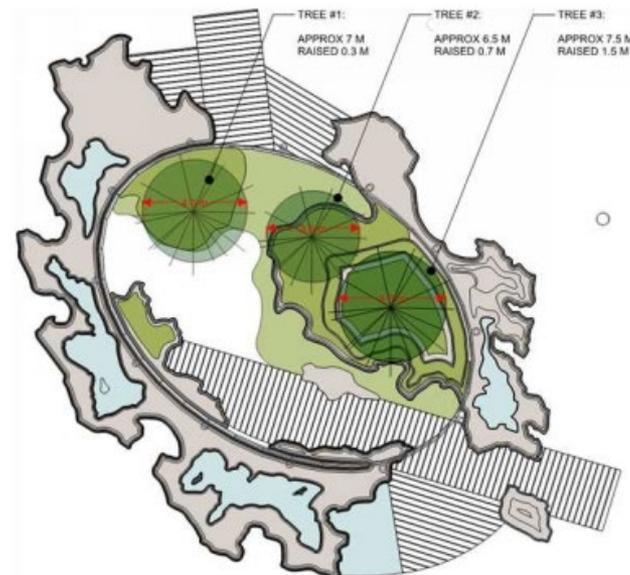
Presentation Outline

- Vancouver Airport
 - Plant and solar focal point studies
 - Art projection studies
- Annual sky and sun modeling
 - Annual sunband method
 - Periodic sky generator
- IESNA Daylight Modeling and Simulation task group
 - Documenting Modeling and simulation standards
 - Developing gold standard annual test cases
- School studies
 - MLK Jr Cafeteria retrofit
 - Jones K-12 / Robeson – new school designs
 - Hillwood HS – gym and passive wings
 - Vanderbilt – Melanopic lux calcs



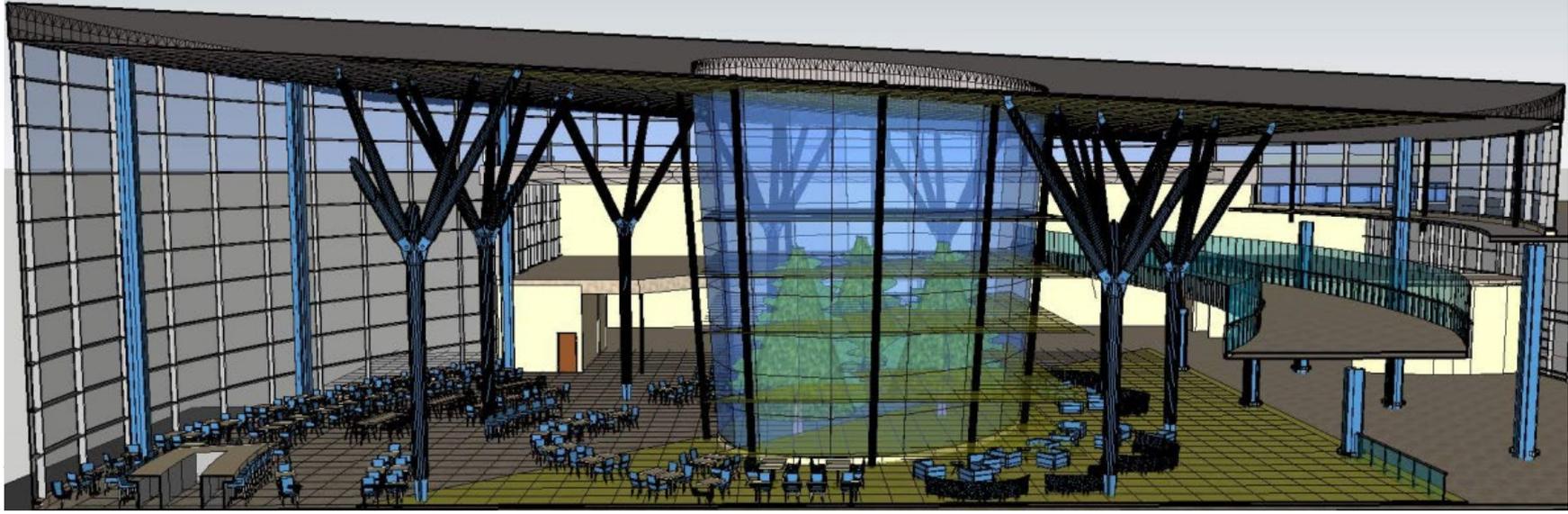
Vancouver Airport Plant and Visibility Analyses

- New public gathering hub in new airport expansion wing
- Local natural landscape exhibit in exterior glazed atrium
- Concern over adequate light for plants and focal points creating too much light
- Concern over visibility of exhibit and interior stage areas
- Concern over light projection based art installations



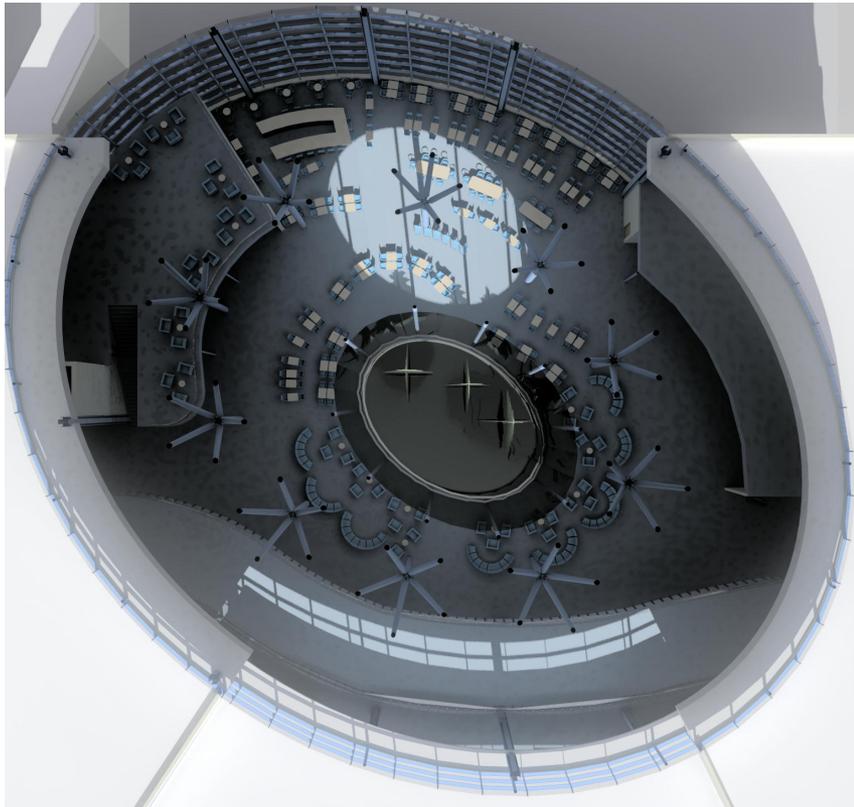


Model section





Model renderings

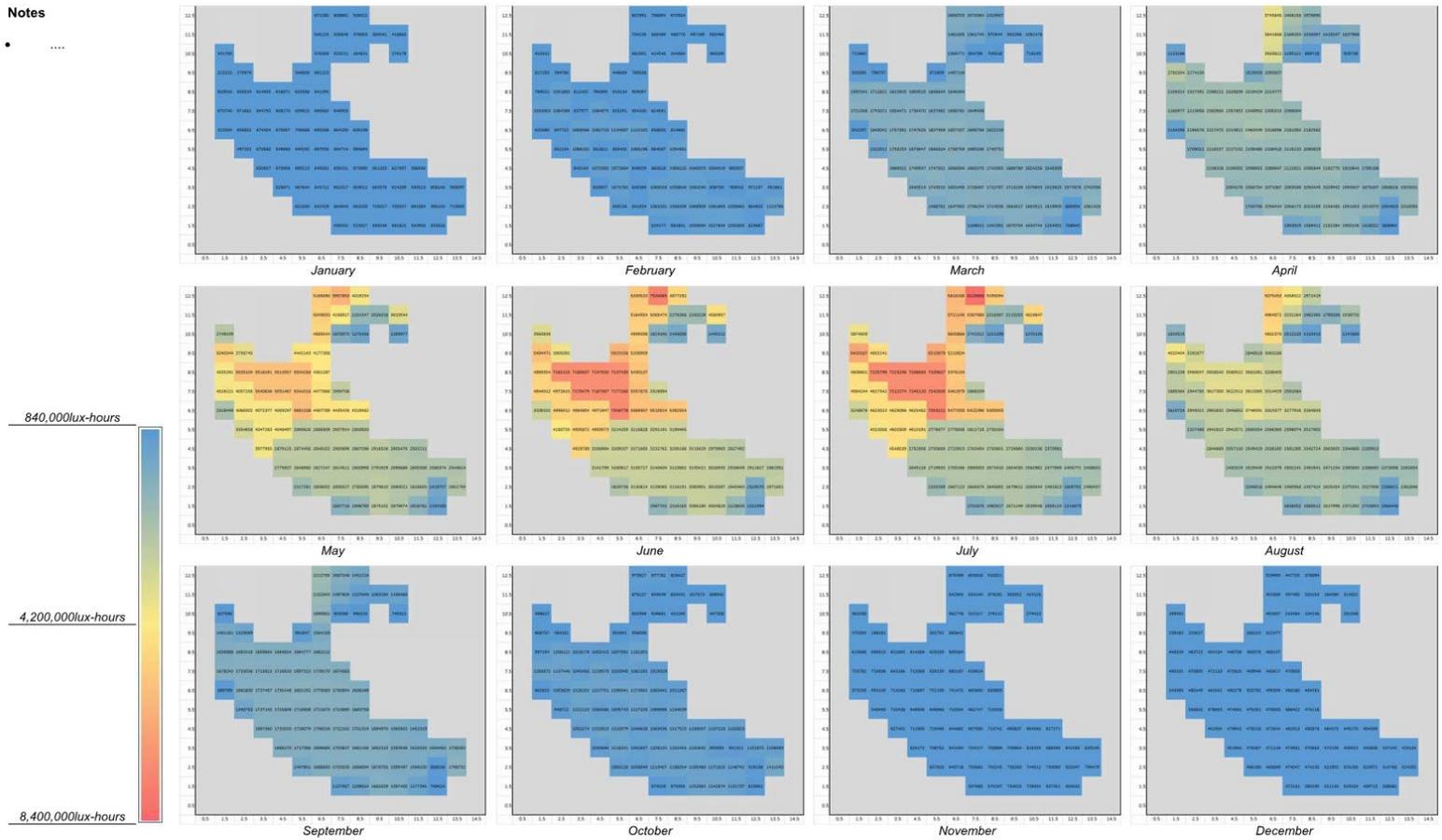




Daylight for plant sufficiency – 0.5m high

Notes

- ****



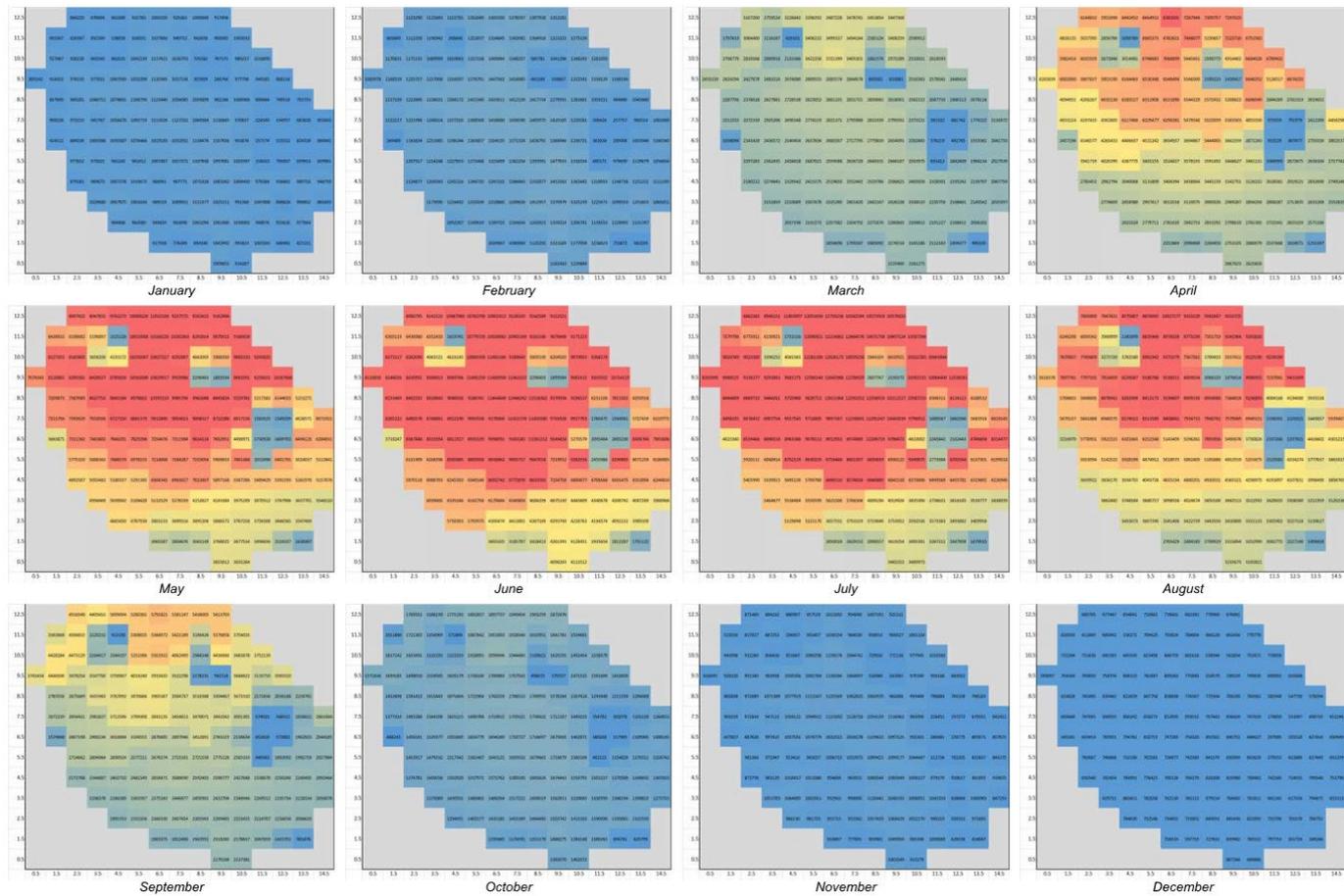
Daily Lux-Hours	Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Mth Lux-Hours
1	18504	7911	19194	20969	16428	23593	23196	10273	20758	12872	16539	20666	6910	22111	20112	26762	11006	15019	4589	26821	22813	7354	22038	21274	16034	15557	29081	25267	31681	21399	33311	590044	
2	28368	10115	5545	27023	29933	31732	30247	34707	28501	36328	14637	14556	36882	36454	44544	46049	16721	41897	38520	27710	45210	50481	37731	39015	39271	40998	14584	18255				866014	
3	45028	51977	42505	35163	50390	51021	18537	31216	42401	63242	61611	34772	38183	40847	32425	40720	70586	26375	53986	67032	35636	71392	75804	34209	35091	34412	78876	75983	27309	60682	76734	1504145	
4	43087	45003	57627	55044	55100	71443	78653	28866	68872	92098	40110	62753	55986	23157	62765	94034	40089	86198	73809	89920	95283	68921	52181	85997	68920	68824	89775	87419	74159	114633		2033729	
5	123589	89848	87556	94874	20633	95583	98386	98432	119723	111887	108209	62883	95915	136703	68230	125221	113191	117716	134823	131969	154629	131840	145019	93308	100034	144318	133605	154937	65178	104872	155993	3419105	
6	125563	123077	150366	142298	132278	153196	145551	145238	147237	163036	141869	163879	114333	72343	60932	155228	160023	120488	159959	110307	138348	147062	161027	128611	119010	108348	117633	146396	151905	134554		4040095	
7	144258	143067	142870	155831	154227	143391	71566	166354	136589	142094	148812	143659	134513	136923	132267	130054	144725	92572	65283	63548	106650	116417	116746	117749	117007	128012	100152	116536	120589	116572	104978	3854009	
8	108193	120704	98660	121311	99355	97418	123364	83988	84586	104167	78468	79767	87669	59760	65567	89029	86757	77276	92915	92088	104886	87483	84333	65813	54317	55669	82202	67556	92040	91050	87284	2711676	
9	72112	78366	48775	83713	45188	83040	43090	42362	40939	43490	41997	39659	37867	71285	63259	40095	35398	38710	48325	72739	33184	55103	38642	53090	47399	65731	30788	34947	94049	41923		1252032	
10	58005	32934	41986	41750	55675	44237	36719	39174	44203	14795	43587	53121	10487	33150	34811	47955	12074	26204	44837	14640	13844	37337	36946	14256	35342	11141	12050	34312	42613	35559	13338	1017080	
11	32020	29749	33488	26528	14895	17903	8758	26146	32730	7833	5512	23148	32227	32082	7265	20404	26080	23441	28525	21653	20485	25824	5764	22010	27512	11387	9801	19789	8882	11338		613167	
12	9775	13068	23016	20881	21394	20737	18216	16712	16828	19864	5630	11864	15813	12890	7164	6341	13112	4440	5817	5013	20944	3357	13432	21644	16619	19948	16545	6420	16264	9785	18537	432070	



Daylight for plant sufficiency – 5m high

Notes

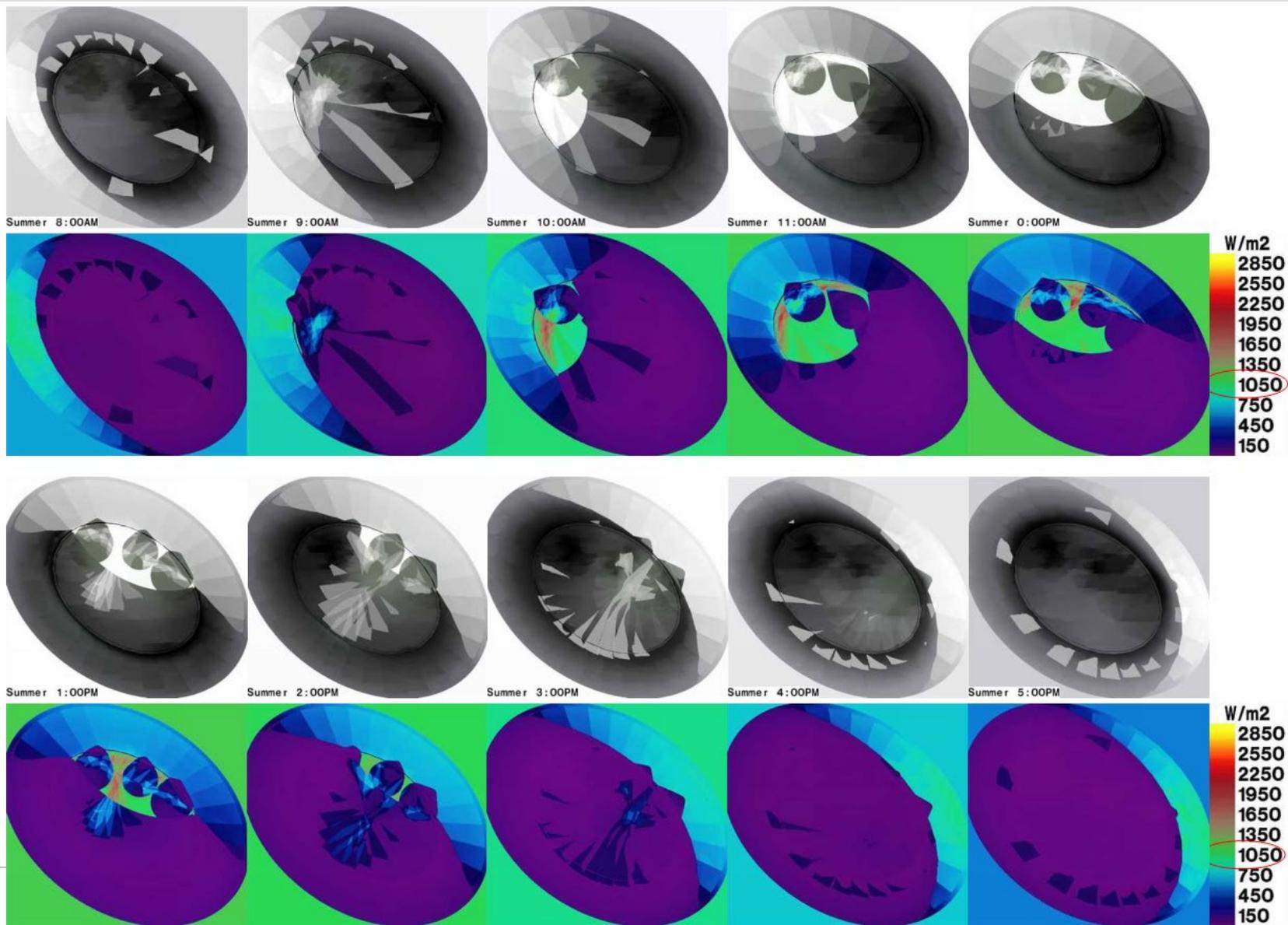
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Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Mth Lux-Hours	
1	32168	11858	35430	33229	24635	38541	35027	15367	37527	19255	24741	31066	10338	37451	35063	42547	16466	22469	6870	40414	34204	11004	33013	31832	24005	23276	44785	37914	47606	32032	49806	919941	
2	42249	15137	8299	37746	44071	46803	40839	50861	42137	49431	21923	21819	45349	54097	62350	62039	25072	46862	40543	41452	44989	60616	56473	58175	44452	61301	21818	27309				1178214	
3	67421	65819	54454	52714	74922	69156	27758	46718	62634	94812	90663	52014	57238	61112	48569	72071	108970	39584	81287	105317	73869	107383	123877	76768	81389	81233	122042	116362	40852	94827	136094	2387923	
4	109120	108701	126653	123500	130276	120601	128329	43197	135985	170584	60665	149802	140668	34657	118479	177677	60505	130929	111026	169764	165403	191306	78043	147653	194442	195713	190244	213767	201176	207103		4135967	
5	200544	209523	210096	153792	30883	221015	220236	228609	230175	236481	236158	94355	152542	251347	102575	234206	206687	186515	273607	266919	267804	266400	275129	140772	178853	290247	276330	290380	109778	176304	293427	6511688	
6	193225	190314	310389	234090	246181	317981	309682	306015	305084	268863	286992	298041	176342	108773	91533	299510	324212	186690	301614	172118	220456	301978	319532	205229	181035	168389	179377	300300	275421	209245		7278013	
7	304199	303066	302569	280456	310176	253941	107254	282715	281629	296052	294600	268004	278609	273226	276695	272266	278456	139611	99056	96091	215995	261332	262673	252908	245615	213523	177601	224311	245368	182013	241002		7521011
8	219950	241180	205462	258037	226118	226945	242573	213415	206044	210577	202637	200828	194984	89525	106206	167943	135514	121262	168943	165957	195248	180289	162539	159807	157752	152965	158612	131199	171725	157928	157084		5563246
9	108787	145258	73009	139084	125404	143410	117352	111213	106763	106431	100885	95822	118064	89102	88349	103696	82718	72409	120617	71280	94304	76052	80220	80834	103624	46081	52276	93750	62780			2943586	
10	92569	49274	65100	68164	84503	61642	50567	52656	66137	22132	54913	78882	15711	48735	52273	65612	18101	39200	60344	21915	20759	54838	51922	21376	41919	16672	18033	43254	58121	48303	19962		1463590
11	43169	40194	46177	39527	22286	26788	13105	39031	47980	11719	8245	35140	48296	48326	10868	30617	39470	35485	44171	32738	34887	38805	8641	35457	43672	17094	14750	34136	13312	16972			921060
12	14688	19645	35971	35145	35623	31332	32467	31836	32328	34687	8441	17769	23688	19305	10726	9094	21942	6666	8759	7519	33983	5032	20131	38852	25023	36907	24798	9633	24467	14688	31429		702976

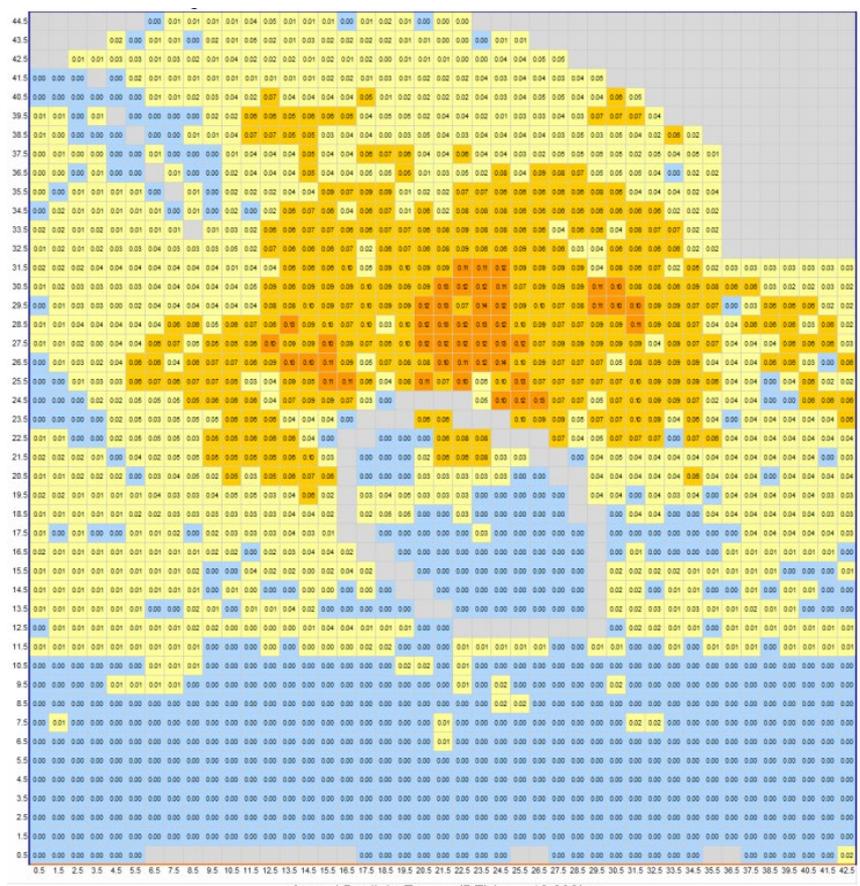
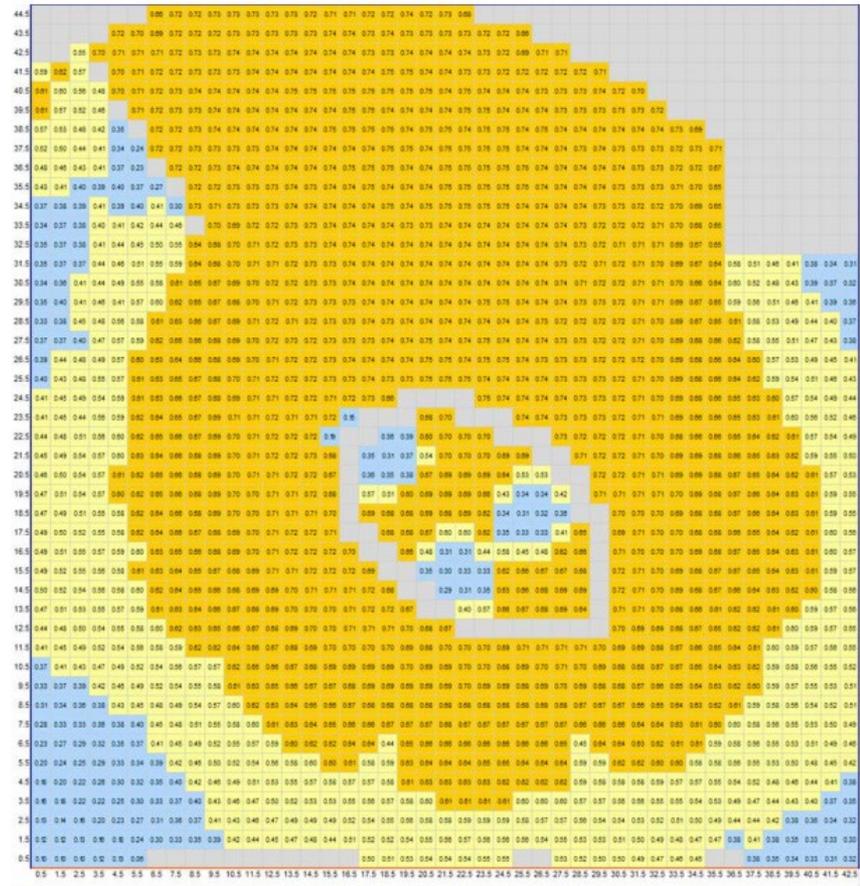


Solar reflection focal point





Daylight sufficiency and daylight excess



Annual Daylight Saturation (base 1000lux)

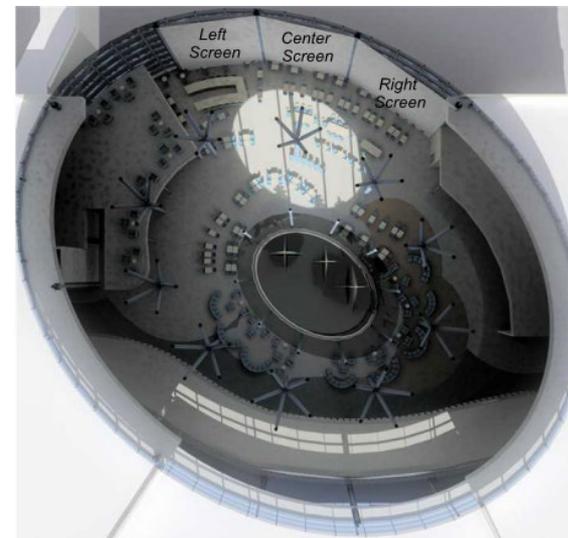
Annual Daylight Excess (DE) base 10,000lux



Interior screen projection



Floor finishes and Projection Screens





Screen illuminance

Left Screen

9.5	541	519	507	515	513	503	508	501	504
8.5	575	558	520	517	504	514	516	516	519
7.5	560	553	517	580	526	521	523	531	534
6.5	511	512	538	576	567	538	576	531	536
5.5	457	494	508	501	545	550	578	543	553
4.5	477	541	486	525	553	547	568	550	581
3.5	484	554	573	586	544	557	658	689	681
2.5	534	678	519	621	532	683	704	661	849
1.5	575	568	693	661	745	926	586	652	954
0.5	555	615	595	528	549	825	846	668	866
	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5

Center Screen

9.5	512	518	520	521	526	524	523	523	528
8.5	524	528	528	527	532	534	539	543	539
7.5	540	543	544	541	581	552	543	567	550
6.5	539	544	556	555	587	555	569	605	608
5.5	558	560	558	566	569	557	605	720	618
4.5	641	558	575	571	597	563	830	615	628
3.5	776	605	659	828	574	661	614	626	802
2.5	756	758	694	613	709	829	627	633	649
1.5	812	628	712	576	687	826	744	635	793
0.5	614	566	792	598	872	878	617	787	789
	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5

Right Screen

9.5	553	523	534	544	541	546	556	559	560	579	602	638
8.5	538	541	547	551	590	560	571	571	589	664	617	647
7.5	552	564	563	570	572	661	586	668	589	599	684	163
6.5	672	572	717	589	590	598	599	596	598	758	617	601
5.5	663	678	581	594	590	605	783	802	809	726	766	642
4.5	677	730	726	708	854	649	630	632	803	774	653	653
3.5	779	678	827	721	729	696	640	754	747	1014	679	1010
2.5	701	1217	814	1195	767	890	657	937	776	779	918	923
1.5	624	989	932	742	749	686	681	909	791	802	1064	956
0.5	738	940	820	649	1263	900	799	830	901	1168	1093	1064
	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5

Annual Average

Left Screen

9.5	2129	2041	2219	2706	2985	2371	2514	2392	2441
8.5	6463	6463	2468	2560	2382	2593	2542	2486	3098
7.5	6437	6389	2312	8062	2369	2497	2539	2608	2700
6.5	2291	2285	3616	8073	7761	3488	8315	2544	2607
5.5	2207	3645	3621	2436	3501	3504	8315	2690	4260
4.5	3864	38672	2206	3548	4663	3489	4448	4470	4217
3.5	4895	38838	38521	38027	4698	3503	47428	47405	47403
2.5	39167	45079	4721	44564	2787	46754	47074	47786	52029
1.5	40733	38842	44437	46427	47079	52291	8768	35055	52081
0.5	38844	40195	38527	3214	3482	47080	47405	47786	52059
	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5

Center Screen

9.5	2483	2393	2371	2597	2312	2563	2499	2595	2677
8.5	2437	2666	2653	2416	2440	2600	2737	3051	2692
7.5	2666	2598	2575	2620	6179	2585	2820	3026	2670
6.5	2505	2623	2776	2520	6210	2565	2774	7166	7174
5.5	2673	2745	2623	2649	2893	2559	7099	50802	7253
4.5	16774	2709	3550	3370	6132	2920	48636	7143	7170
3.5	44229	18146	42401	52502	2825	40598	7060	7097	52039
2.5	41345	45701	18509	18549	41728	50490	18686	18686	18841
1.5	45521	9277	14259	3151	36275	45542	45510	9530	45193
0.5	7419	3016	45534	7986	45843	45527	8489	45181	45199
	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5

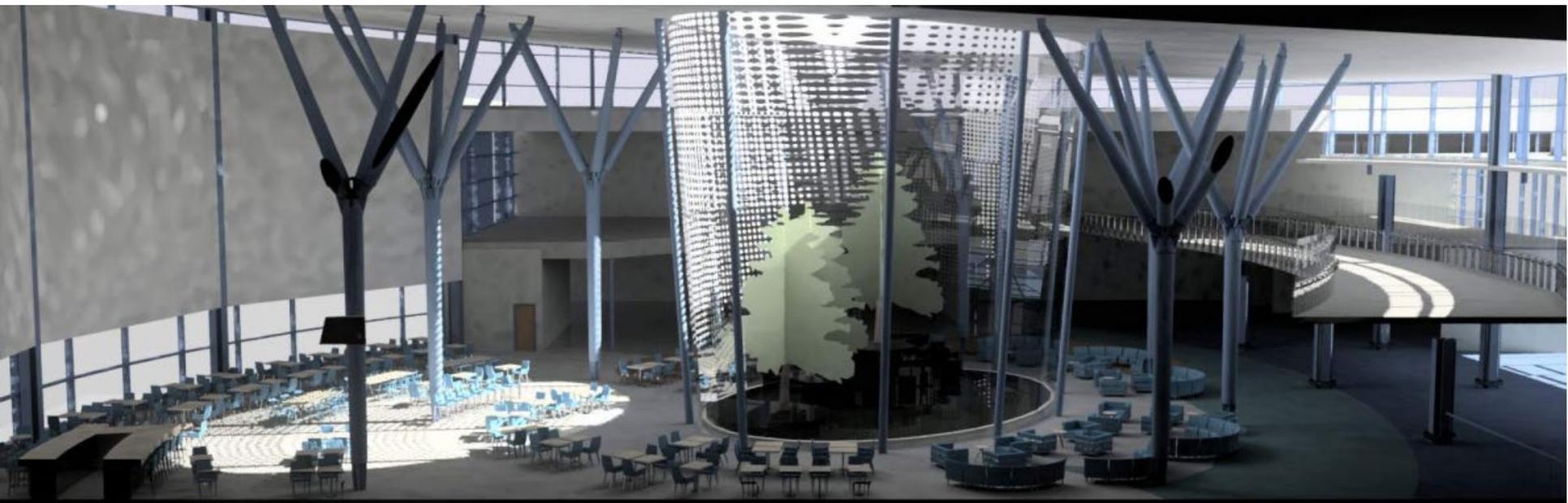
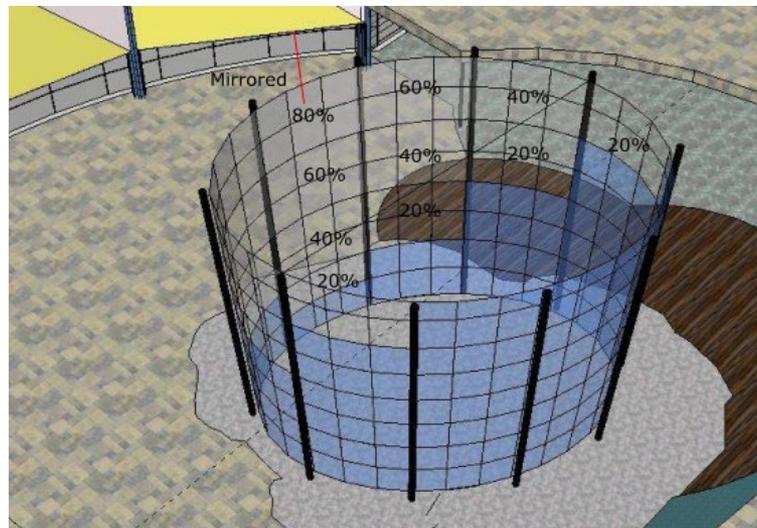
Right Screen

9.5	4611	2633	2782	2730	3036	2763	3006	3334	2909	3243	3361	3547
8.5	3476	2700	2706	2756	5469	2853	2820	2935	3651	21920	4114	3081
7.5	2912	2740	2907	2872	2911	36288	3142	36434	3221	3236	36297	1120
6.5	3969	3114	47605	3995	2906	3052	3014	3019	3268	48269	3211	3433
5.5	15555	15713	2927	3001	3025	2993	52112	54710	54649	46370	48114	3383
4.5	15614	15617	15617	16487	48246	6455	3285	3226	47252	46311	3747	3550
3.5	38758	38023	36613	16483	16482	30522	3578	17329	17252	60553	4045	64394
2.5	15556	54672	16777	59709	16392	48255	3976	47259	17334	17175	60975	61002
1.5	3434	60642	58443	15570	15524	11487	5320	57075	17336	17191	60975	61002
0.5	36743	57499	15853	3596	60131	60441	16516	16727	56306	60580	67830	68681
	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5

Annual Max



Cascading frit for stage visibility/backdrop and reflection





Ceiling Illuminance for sky projections

0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	10.0
0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	10.0

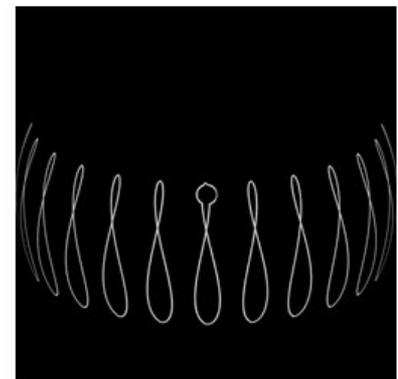
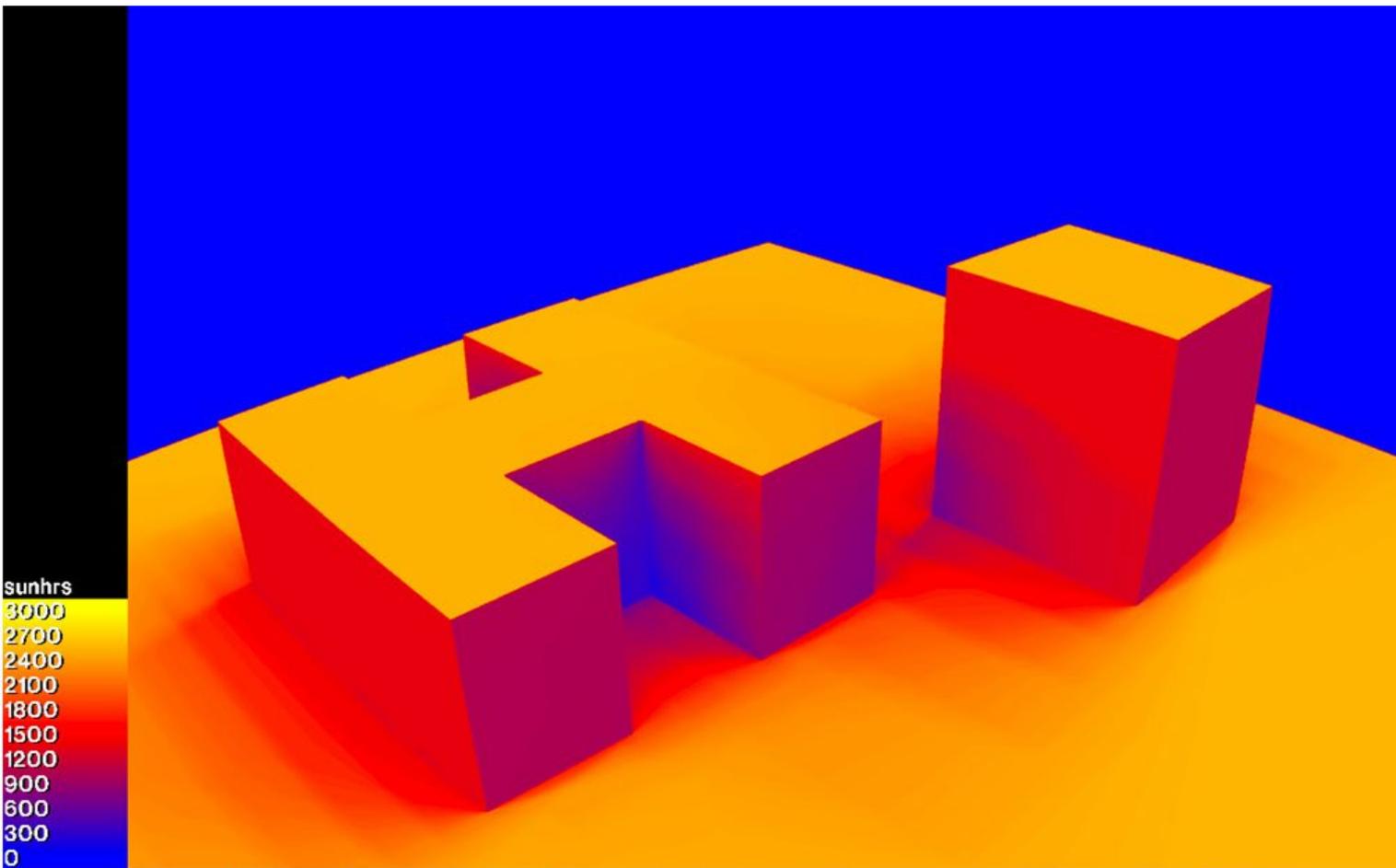


Annual Sky and Sun modeling

- Need for quicker and more accurate annual or periodic sky modeling
 - Development of a sunband method over an 'analemma' sky
 - Development of a new periodic cumulative sky for linux and windows
 - Concept of 'effective' sunlight hours
 - Dynamic 3d viewer implementation and new color maps
 - Work in progress and in collaboration with Perkins and Will
-



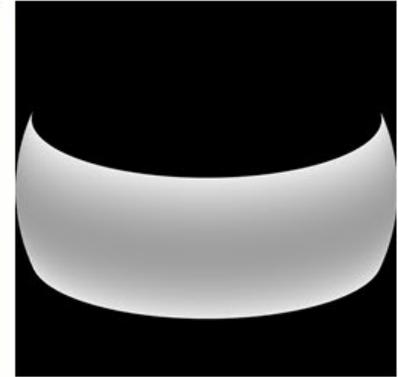
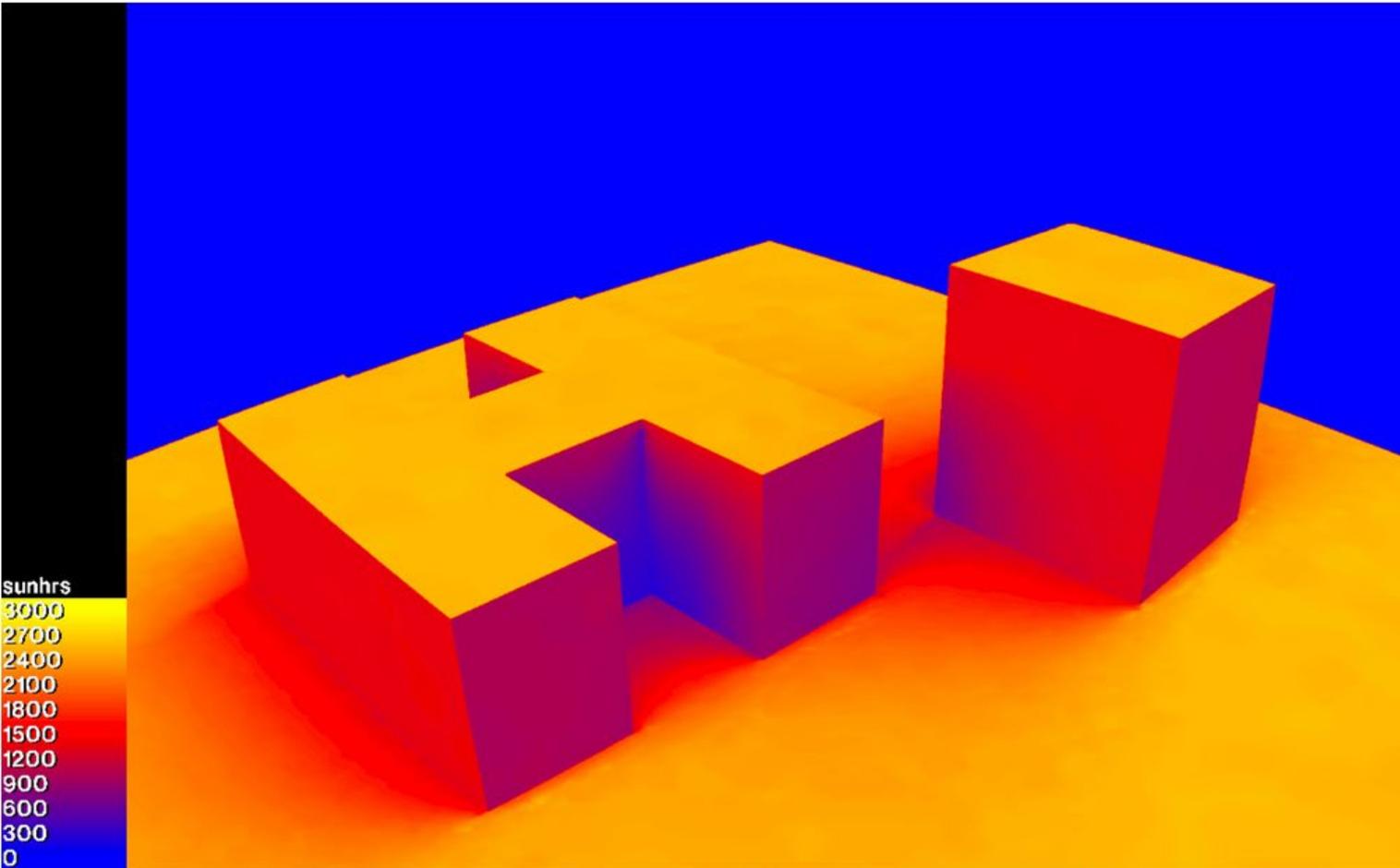
20deg Latitude – All suns



20° Lat All Suns - Run Time: 1,040s+60s (17+1min) - Settings: hhh -ab 0 -ds 0 -dt 0 -dc 1 -dr 0



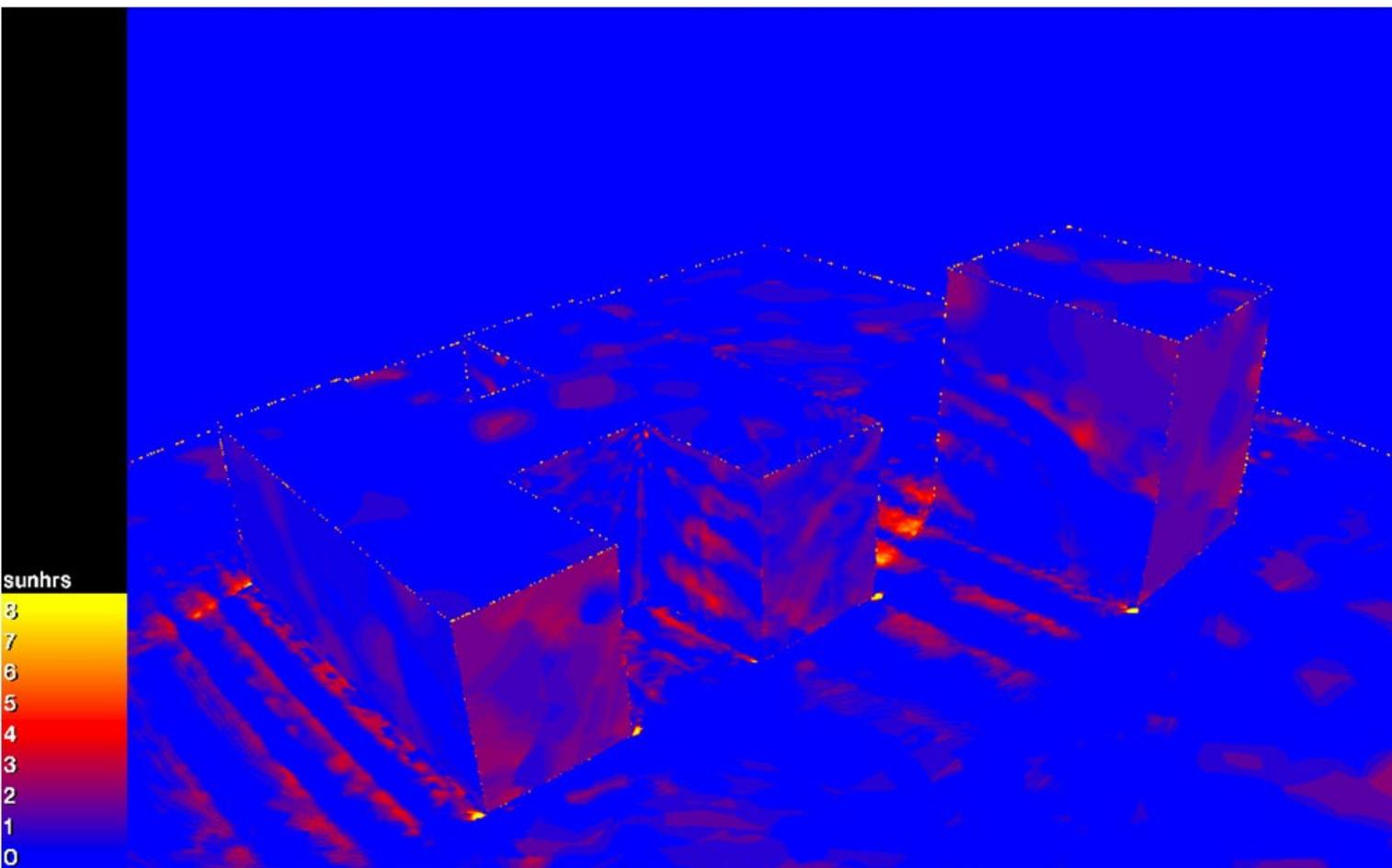
20deg Latitude – Sunband



20° Lat Sunband - Run Time: 21s (9+12) - Settings: mmm -af -ad 2048



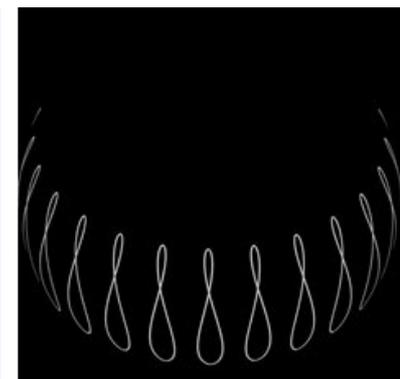
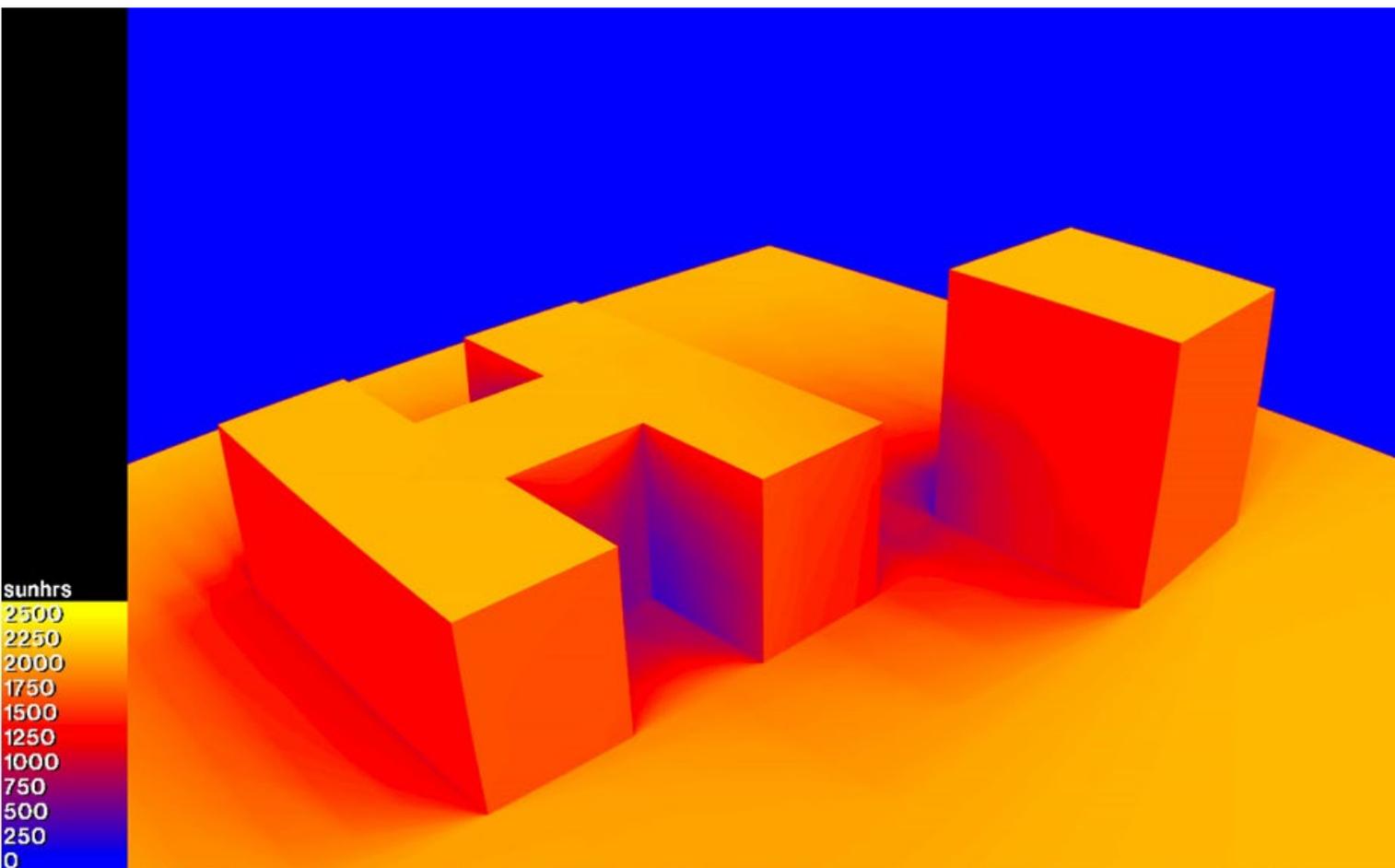
20deg Latitude – Difference



20° Lat Difference (All Suns - Sunband)



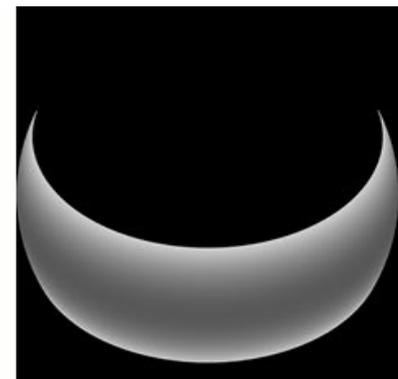
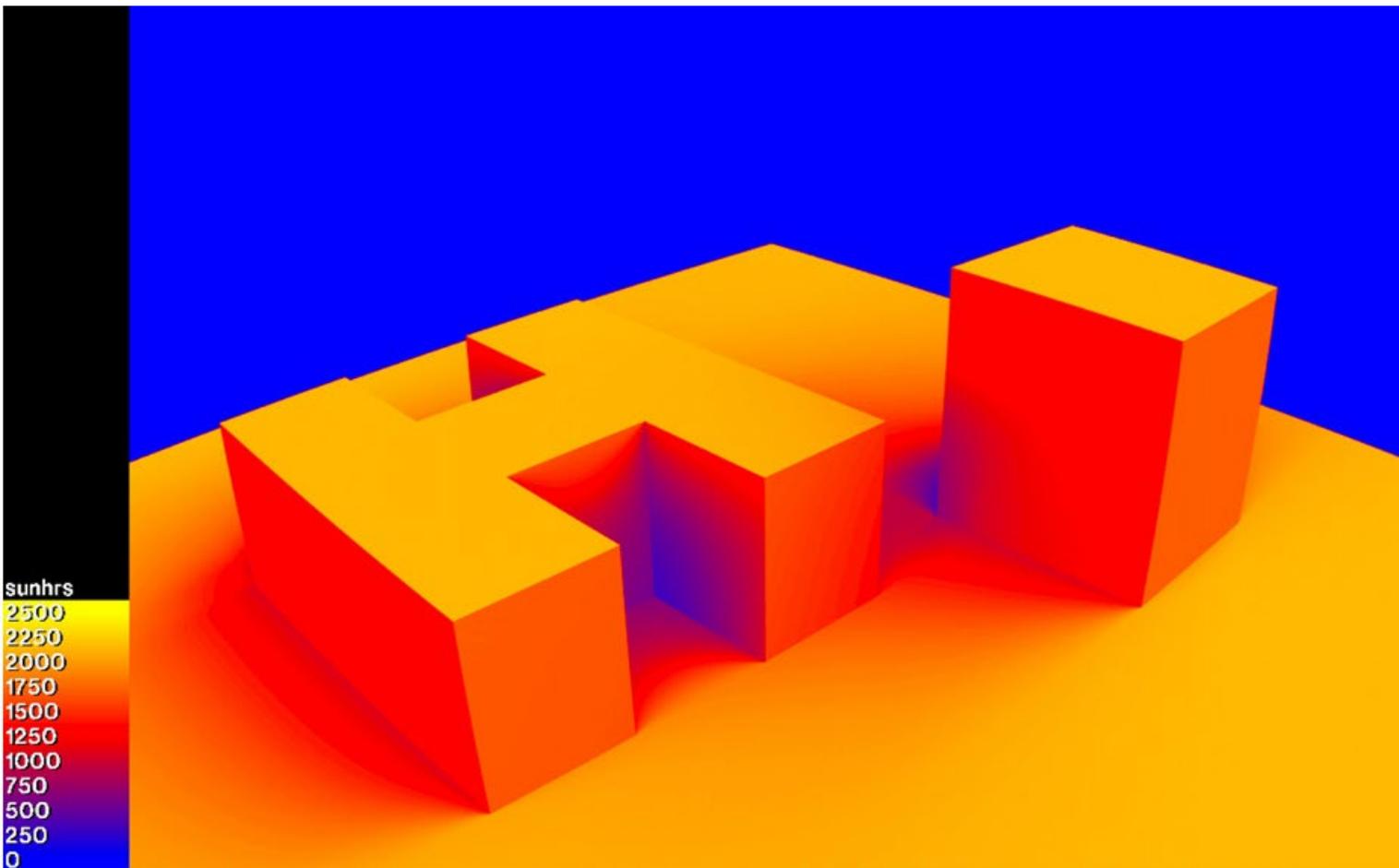
40deg Latitude – All suns



40° Lat All Suns - Run Time: 1,040s+60s (17+1min) - Settings: hhh -ab 0 -ds 0 -dt 0 -dc 1 -dr 0



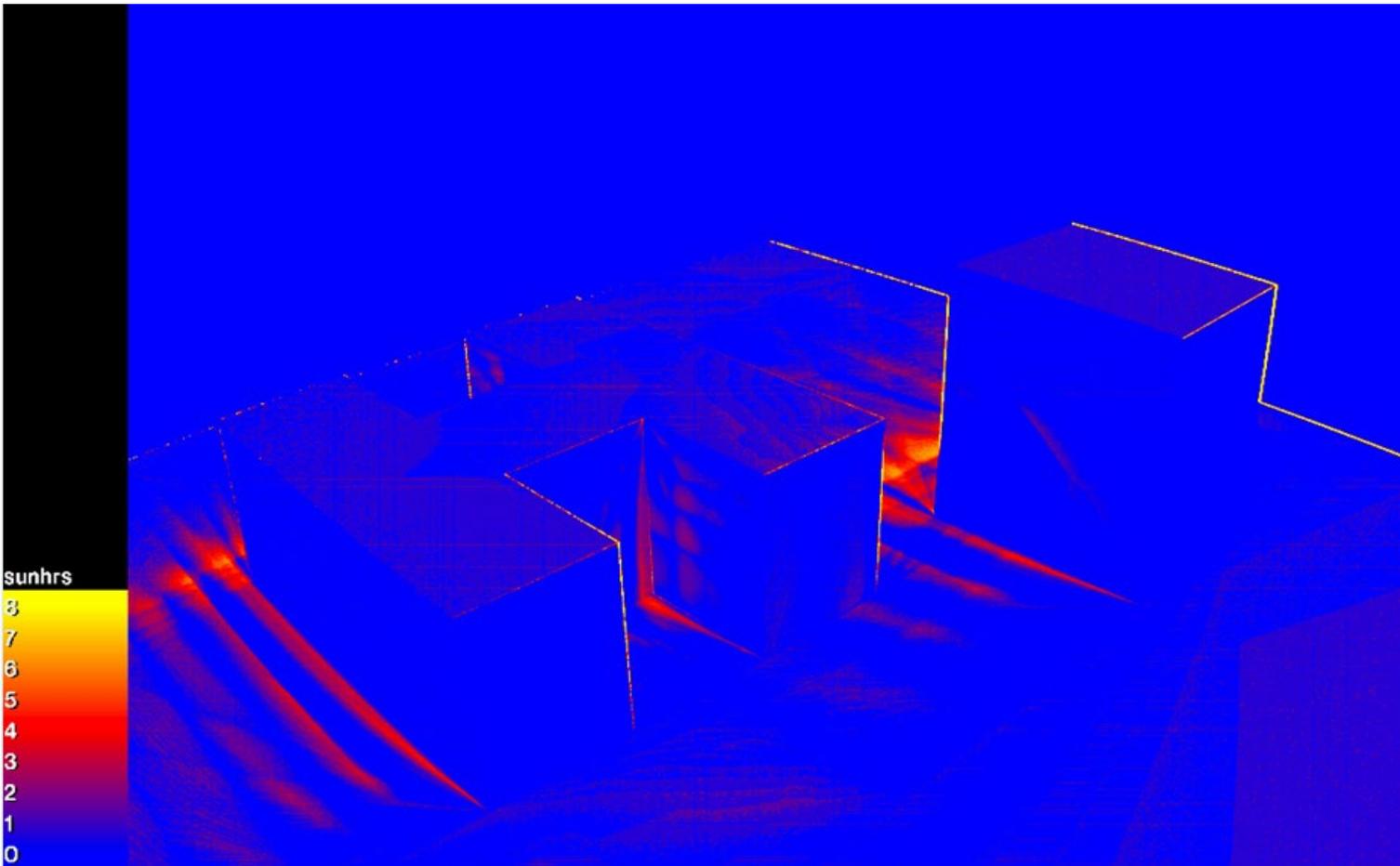
40deg Latitude – Sunband



40° Lat Sunband - Run Time: 71,212s (4.75hrs) - Settings: hhh -ab 1 -ad 8192 -ar 200 -aa 0



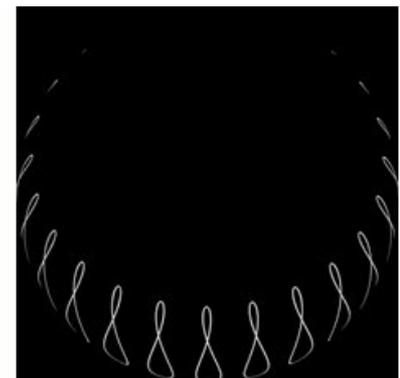
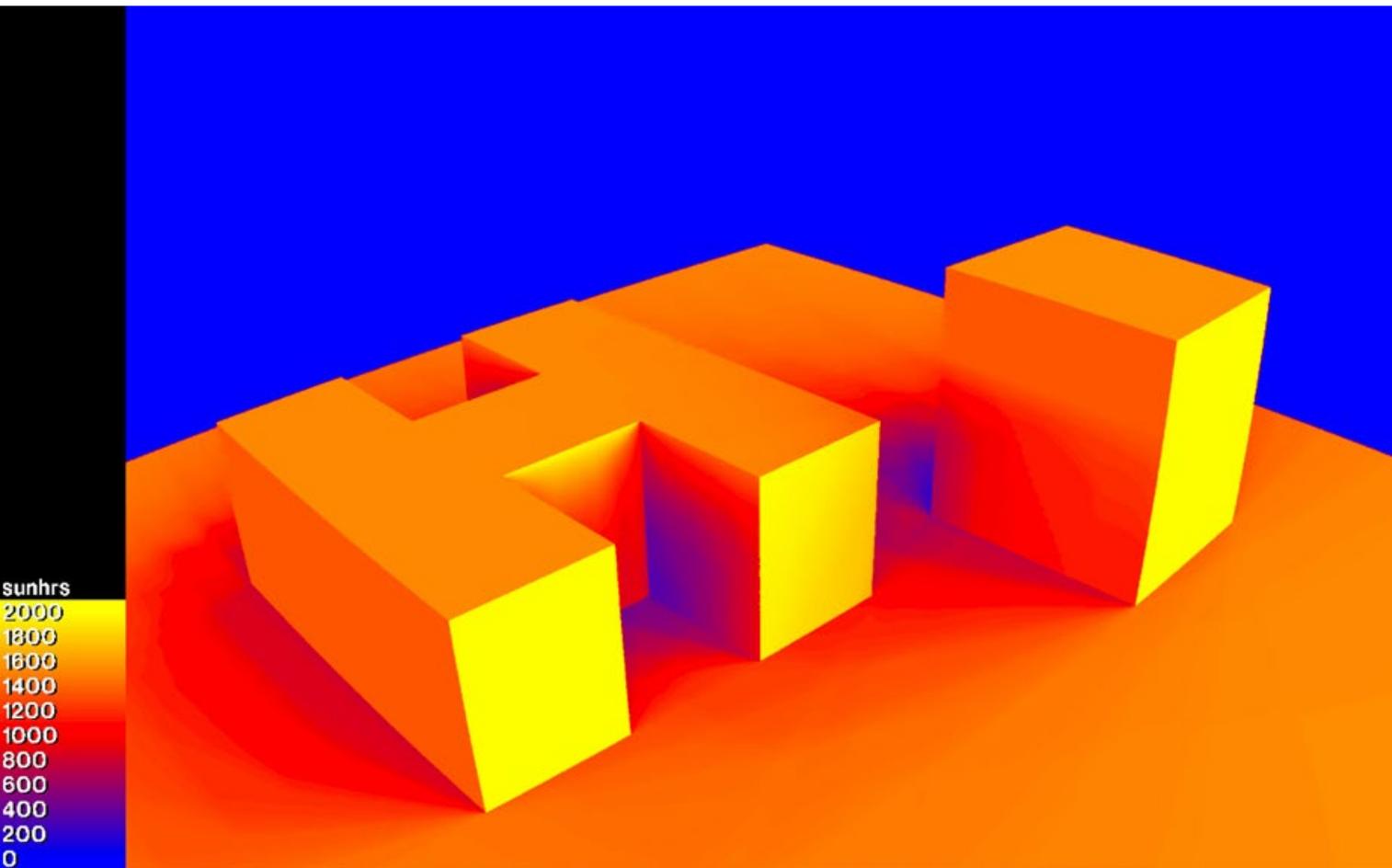
40deg Latitude – Difference



40° Lat Difference (All Suns - Sunband)



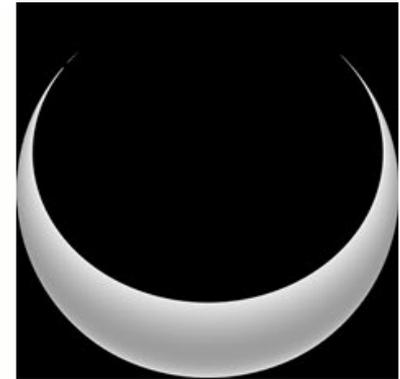
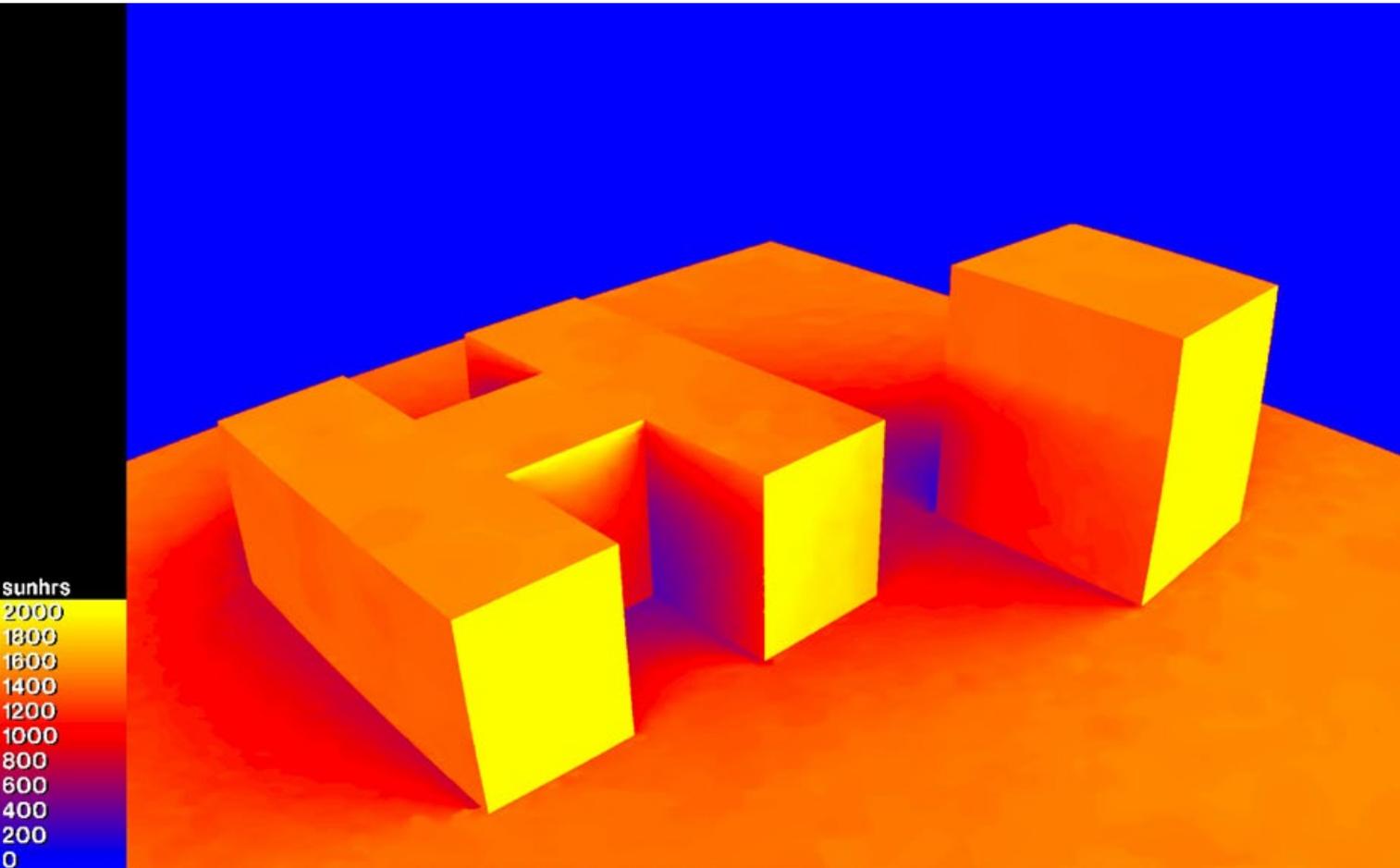
60deg Latitude – All suns



60° Lat All Suns - Run Time: 186s+??s - Settings: mll -ab 0 -ds 0 -dt 0 -dc 1 -dr 0



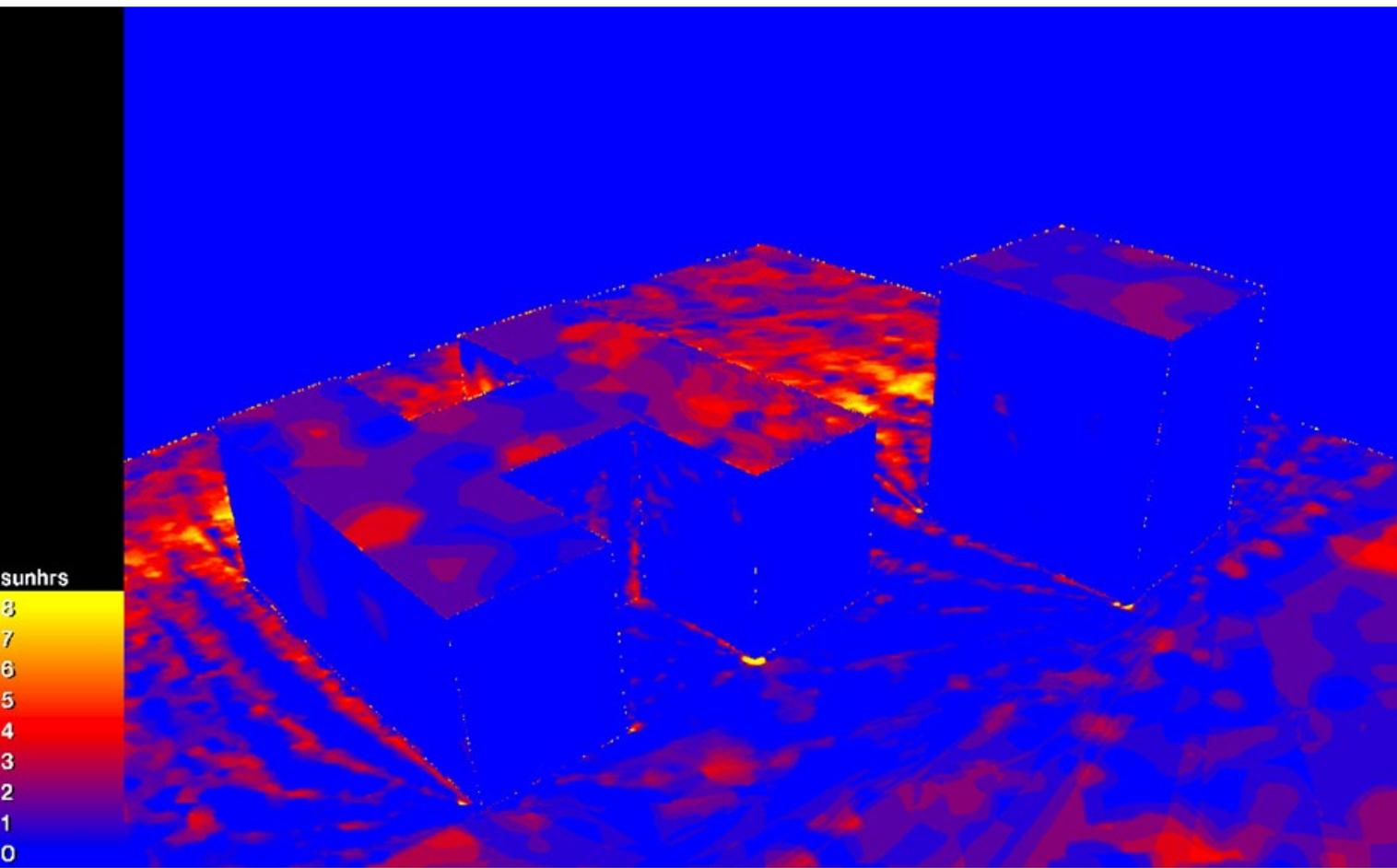
60deg Latitude – Sunband



60° Lat Sunband - Run Time: 23s (9+14) - Settings: mmm -af -ad 2048



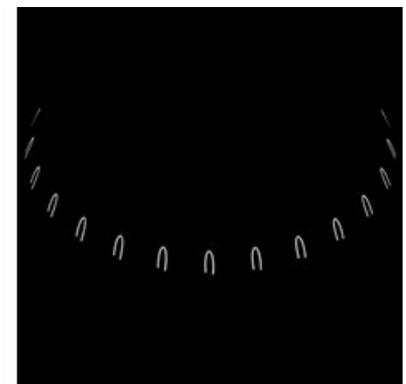
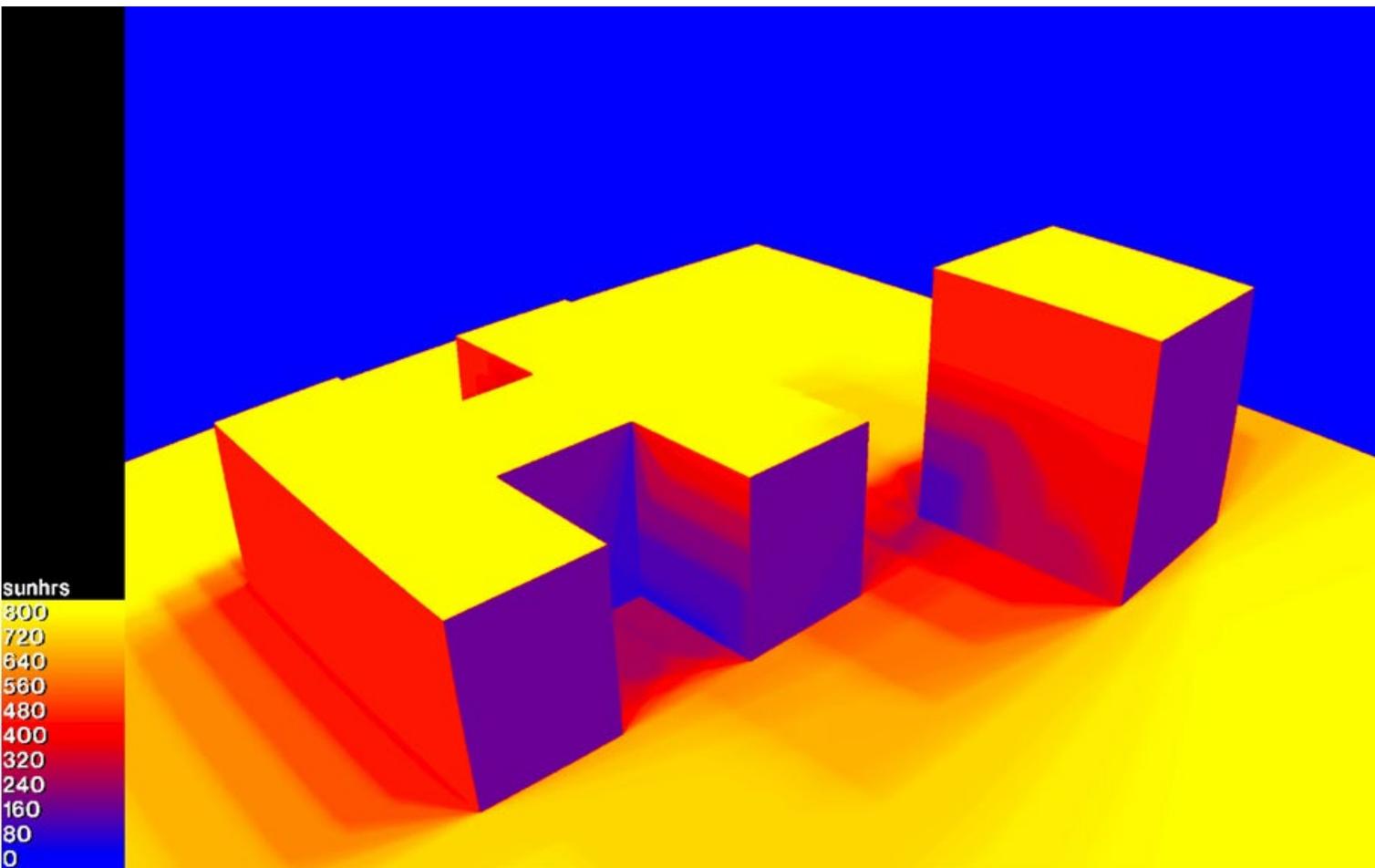
60deg Latitude – Difference



60° Lat Difference (All Suns - Sunband)

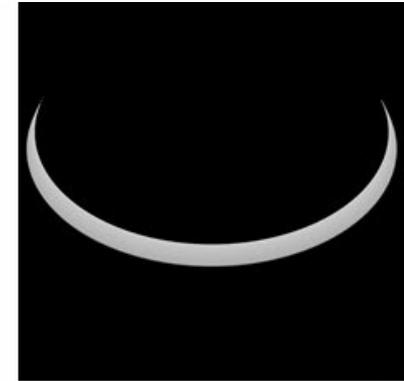
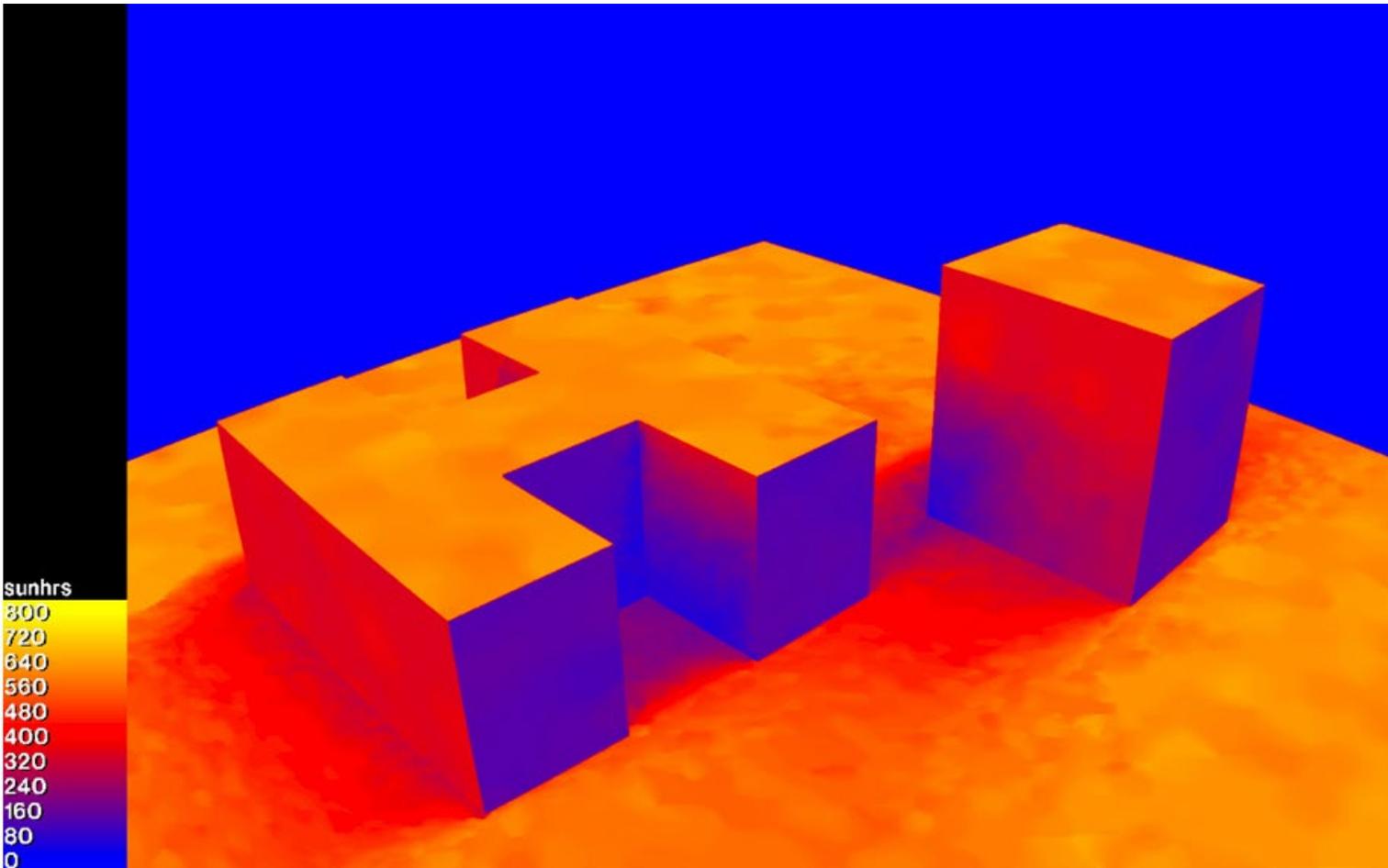


40deg Latitude – All summer suns



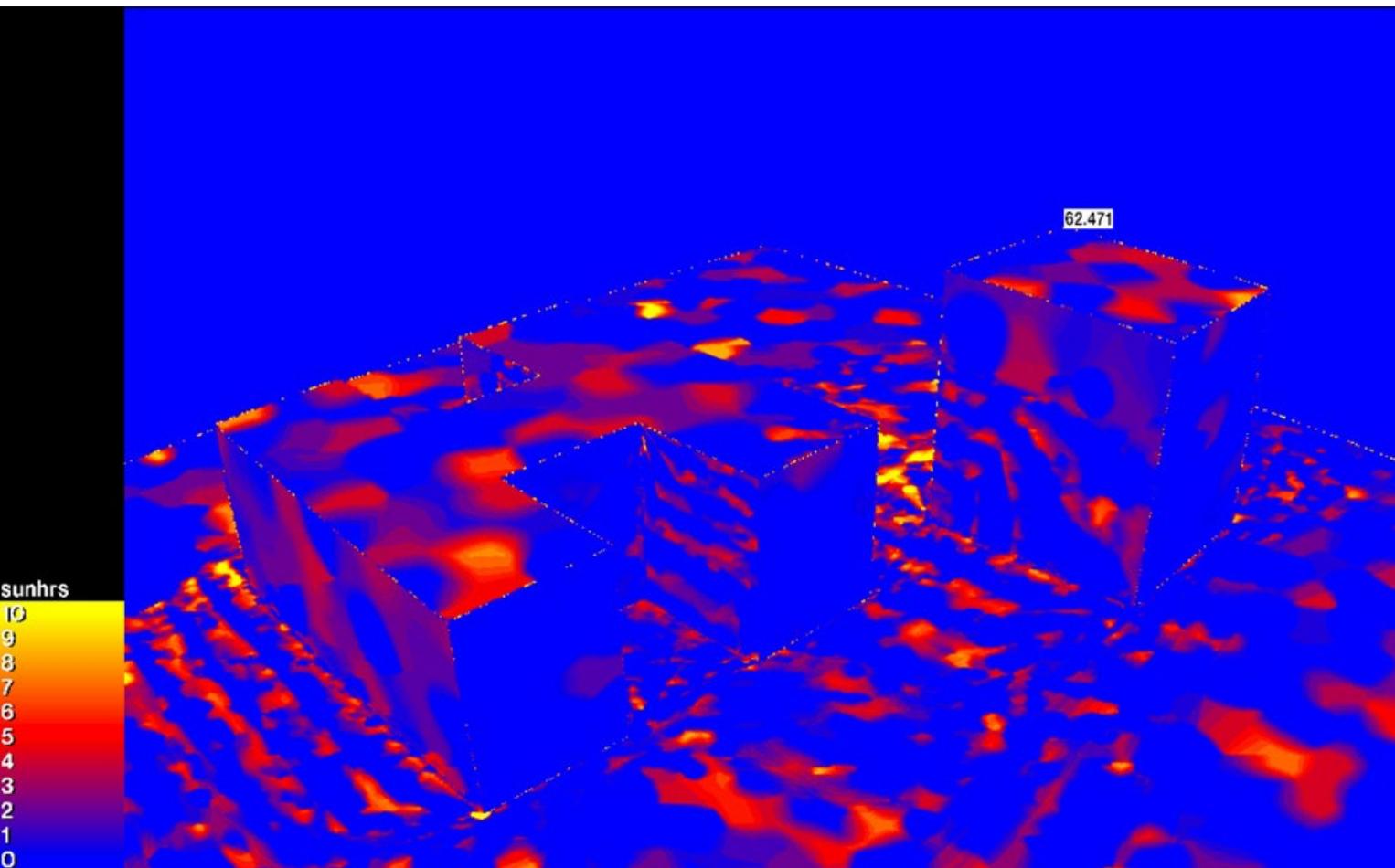


40deg Latitude – Summer Sunband



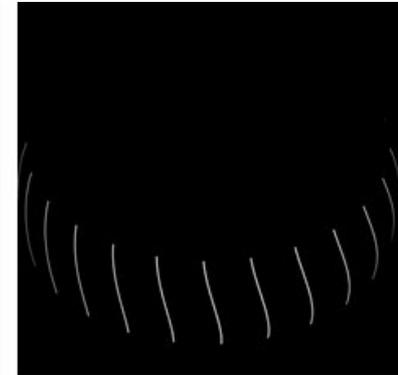
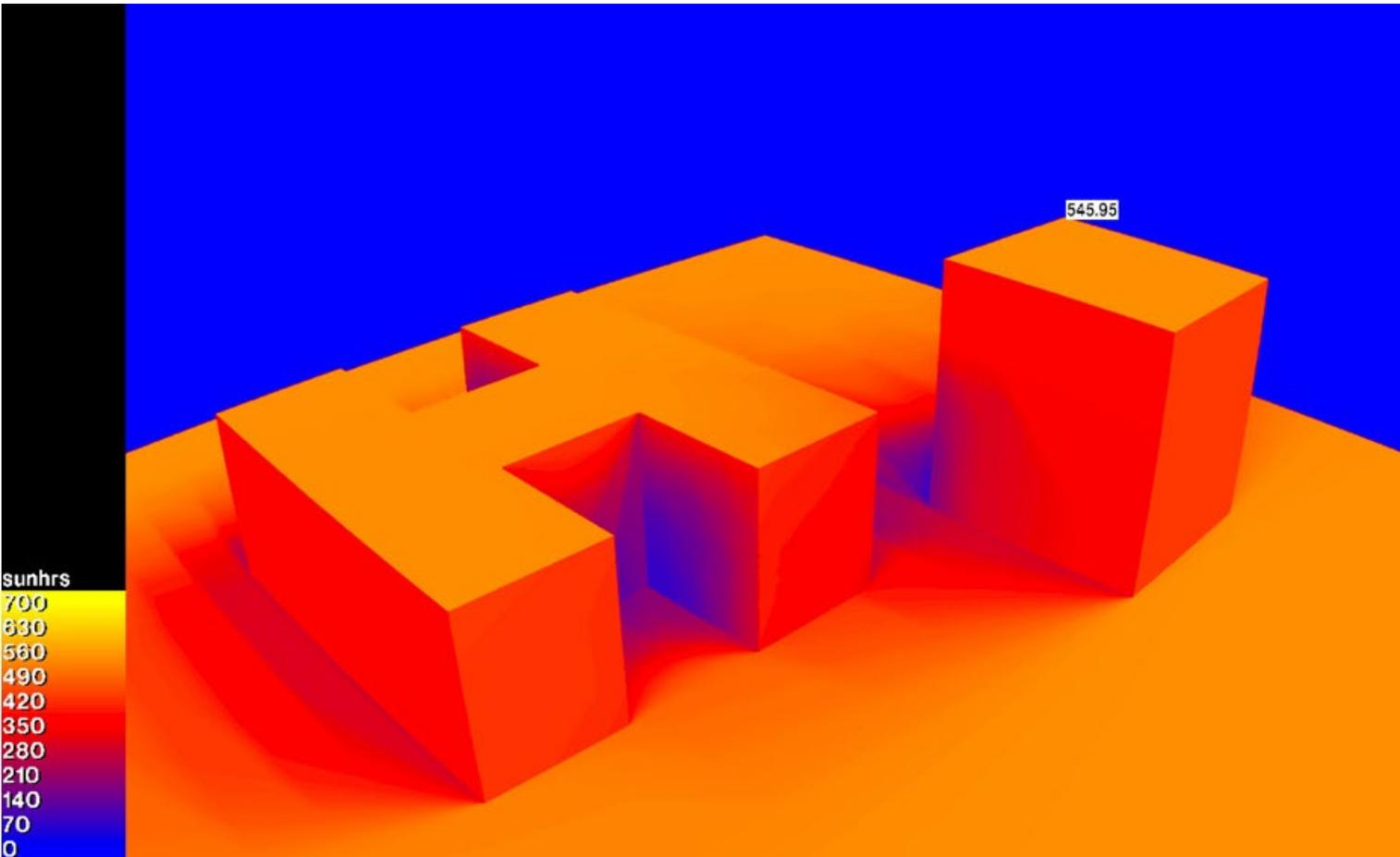


40deg Latitude – Summer Difference



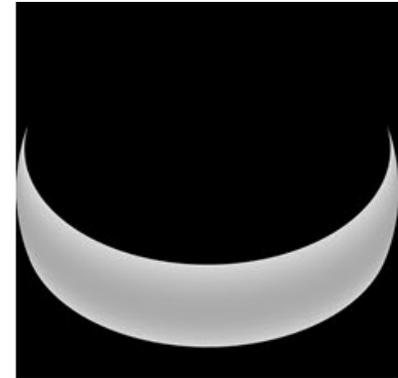
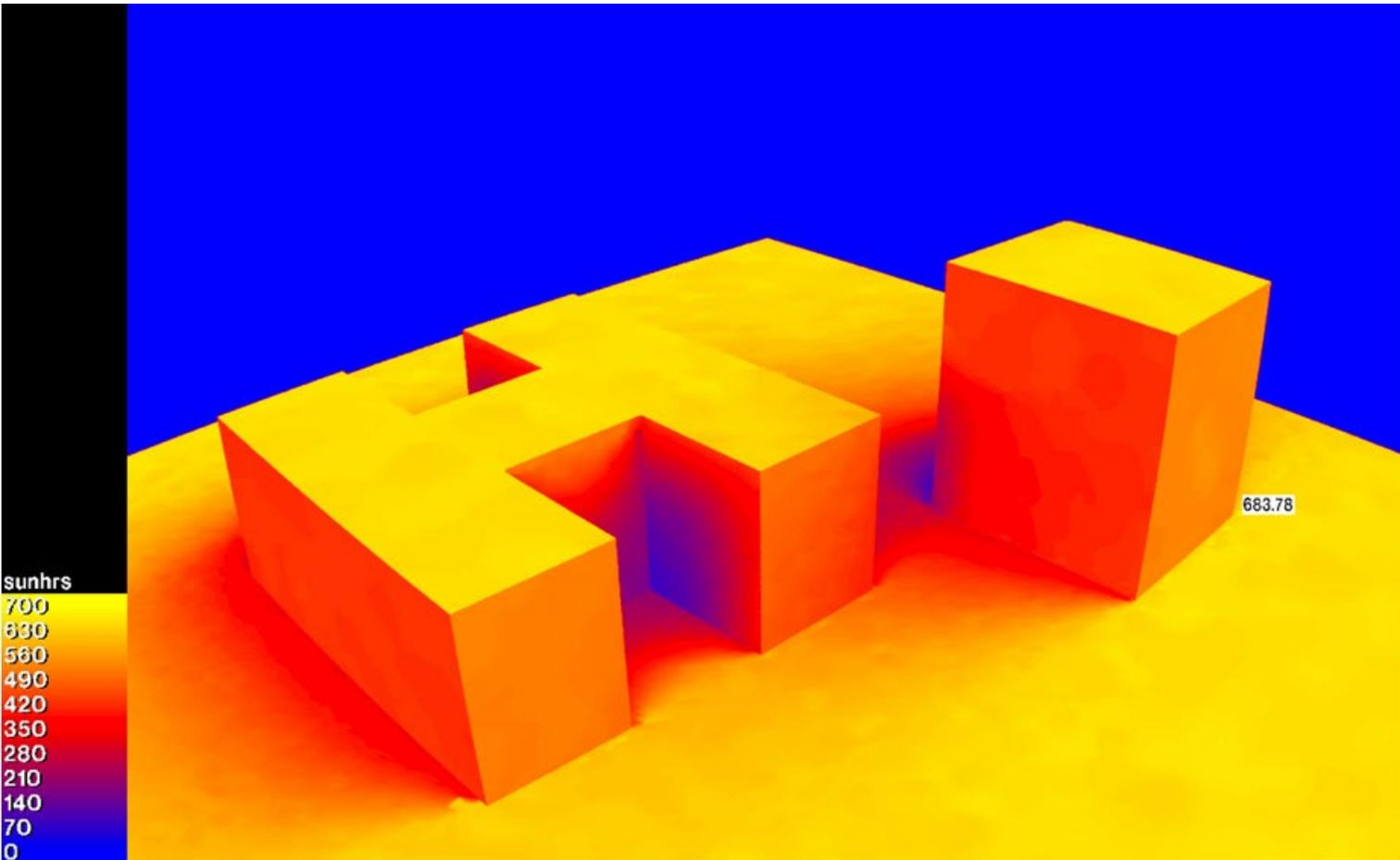


40deg Latitude – All fall suns



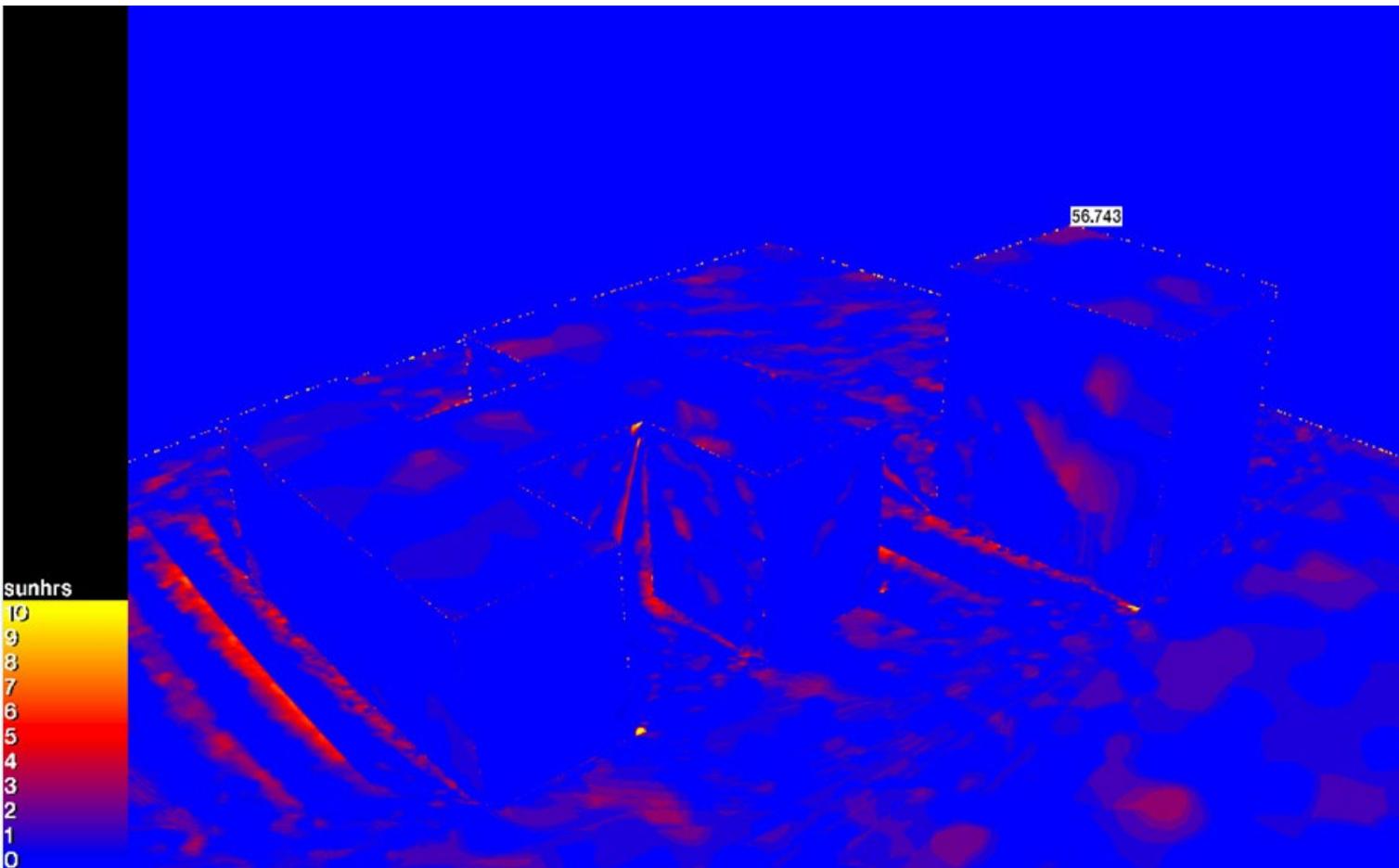


40deg Latitude – Fall Sunband



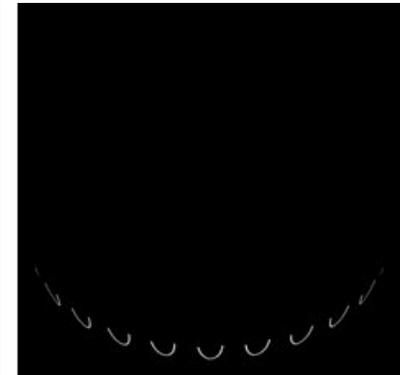
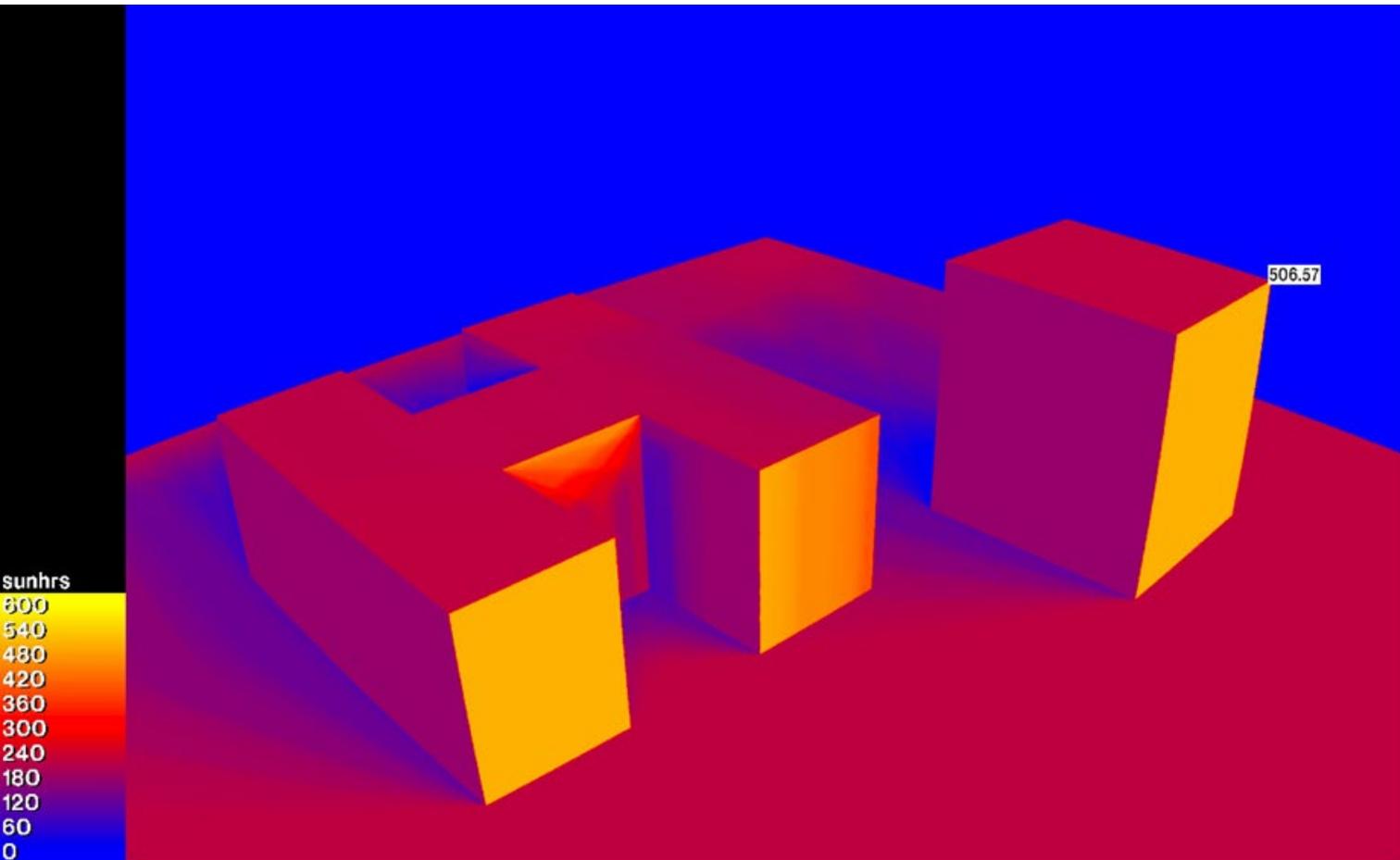


40deg Latitude – Fall Difference



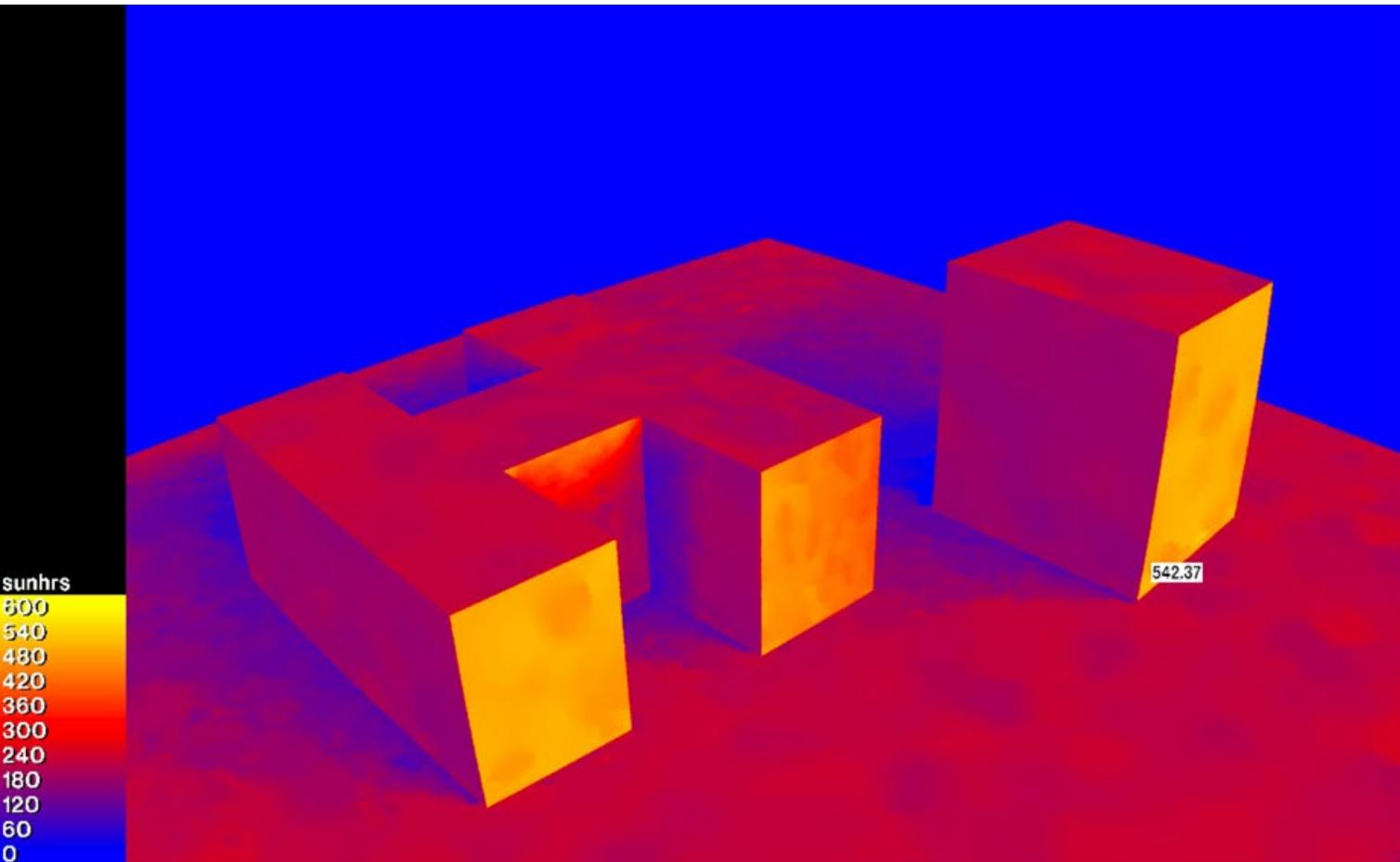


40deg Latitude – All winter suns



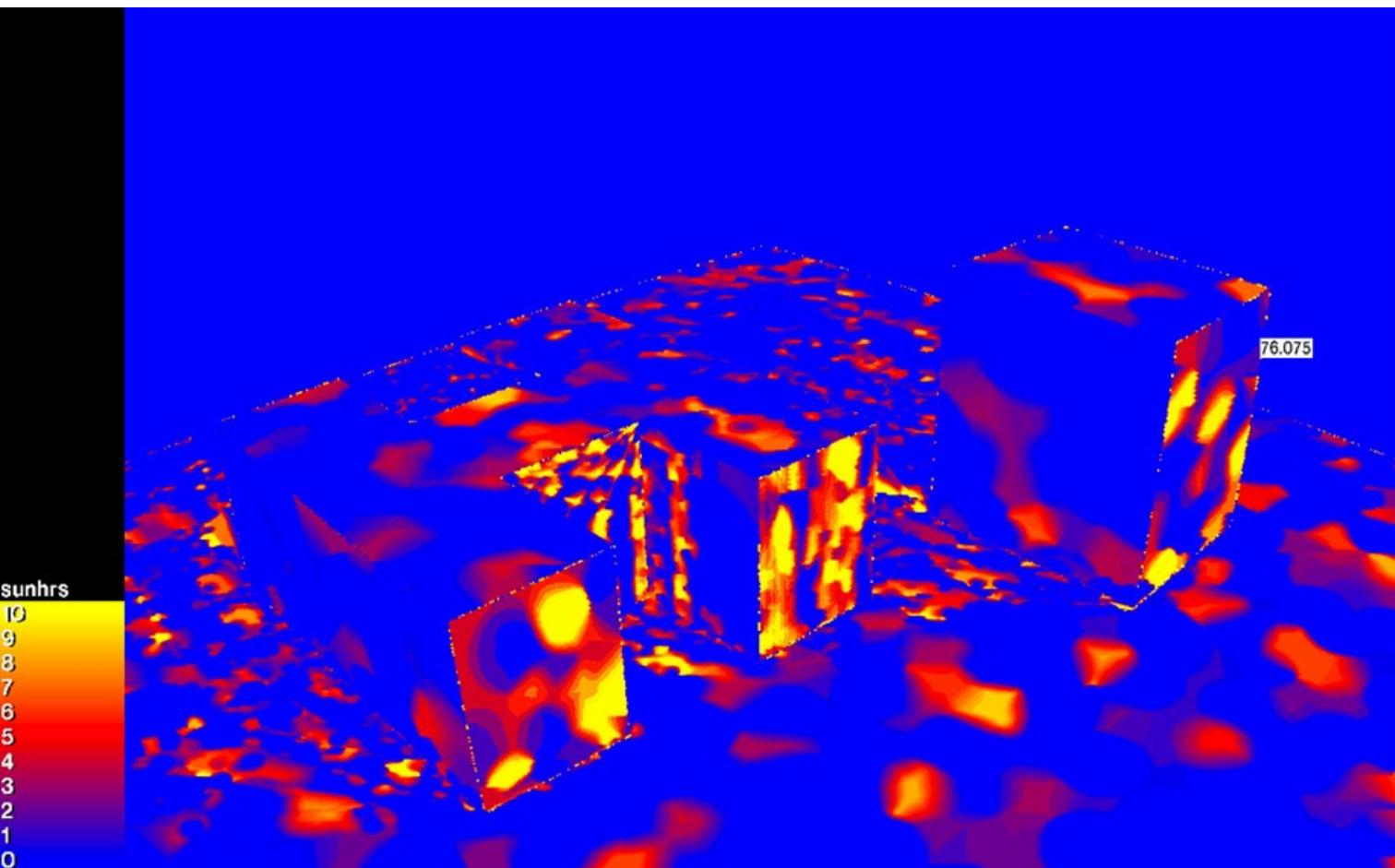


40deg Latitude – Winter Sunband



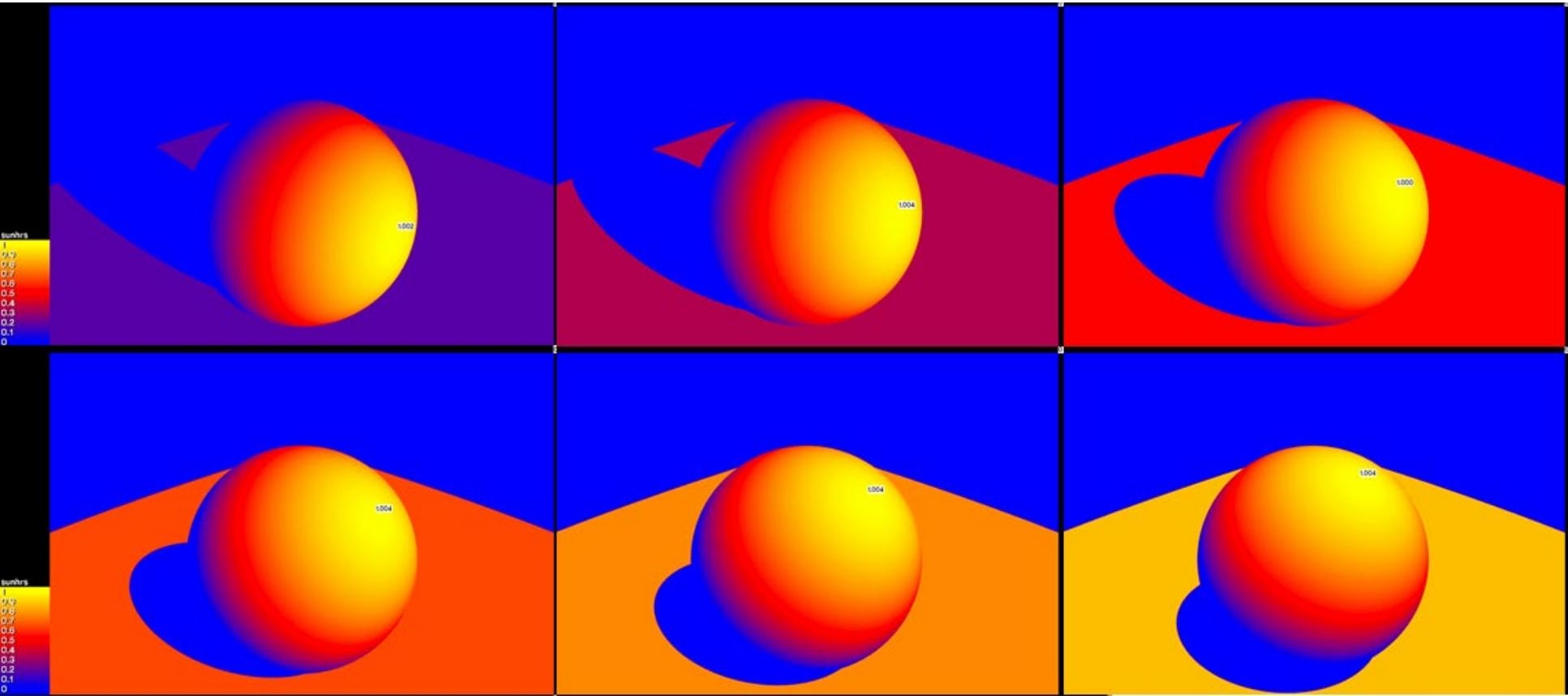


40deg Latitude – Winter Difference





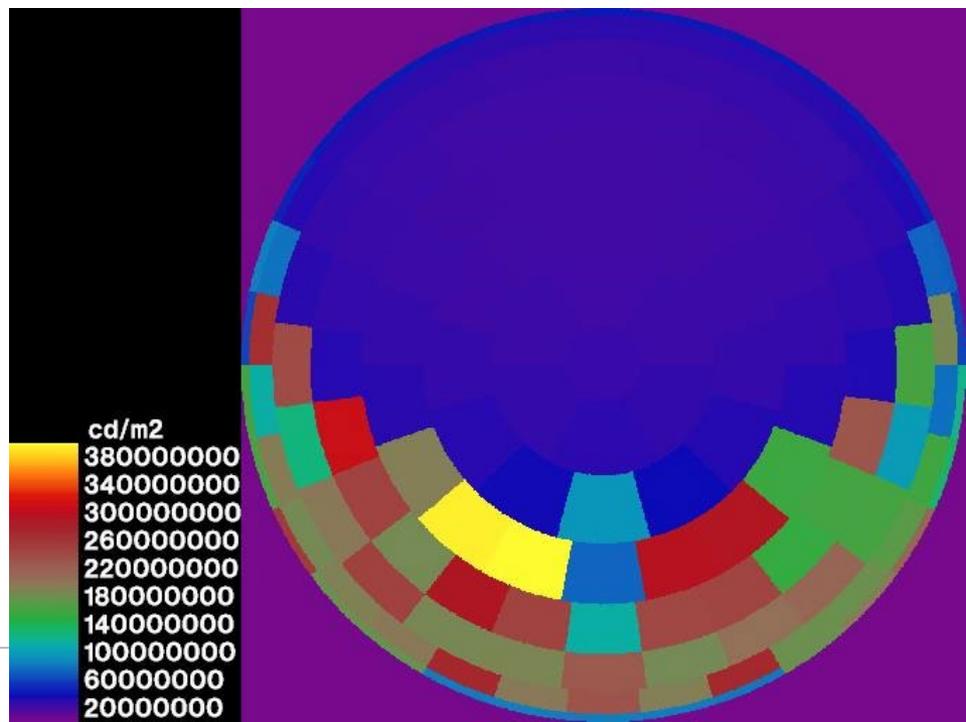
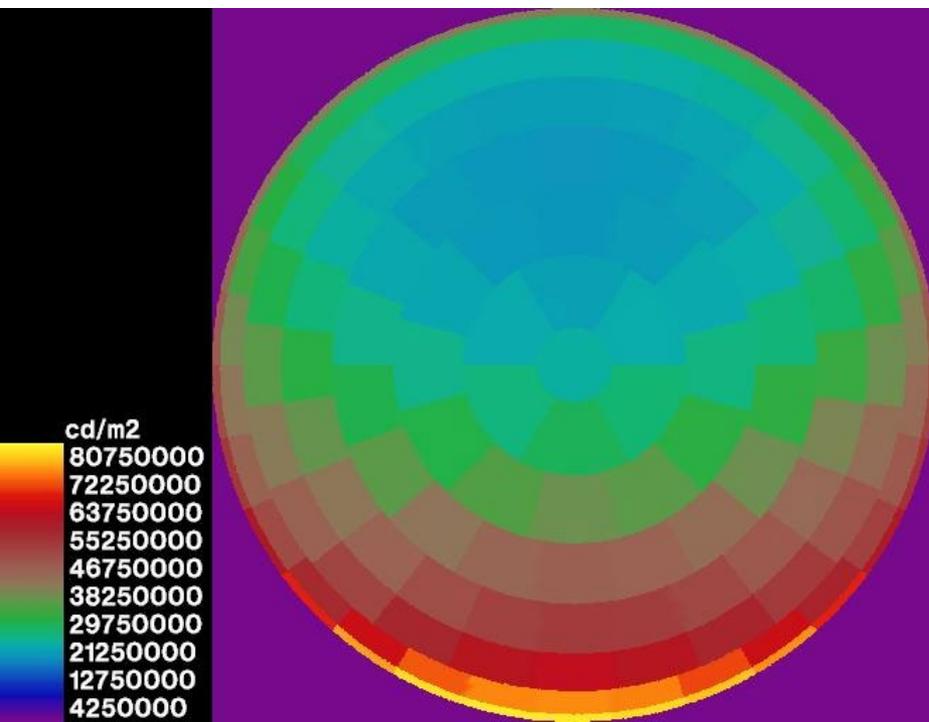
Effective Sun Hours





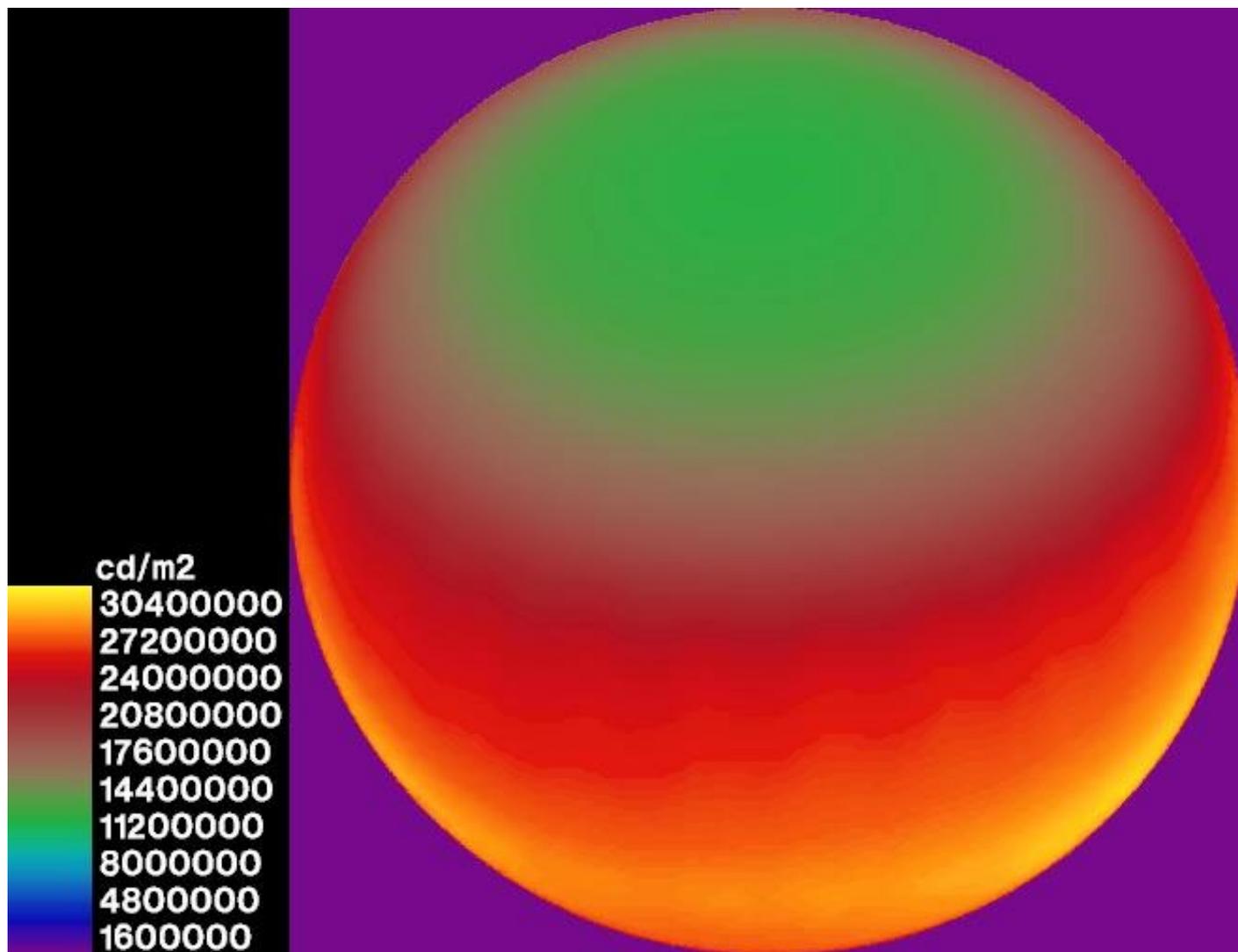
Historical options for annual sky

- GenCumulativeSky.exe
 - Two options – sky only or with solar radiation assigned to patches
 - Very quick <5sec
- Radmap.py
 - Integrated into script to produce radiation maps for a scene
 - Takes a while to simulate 1-5min



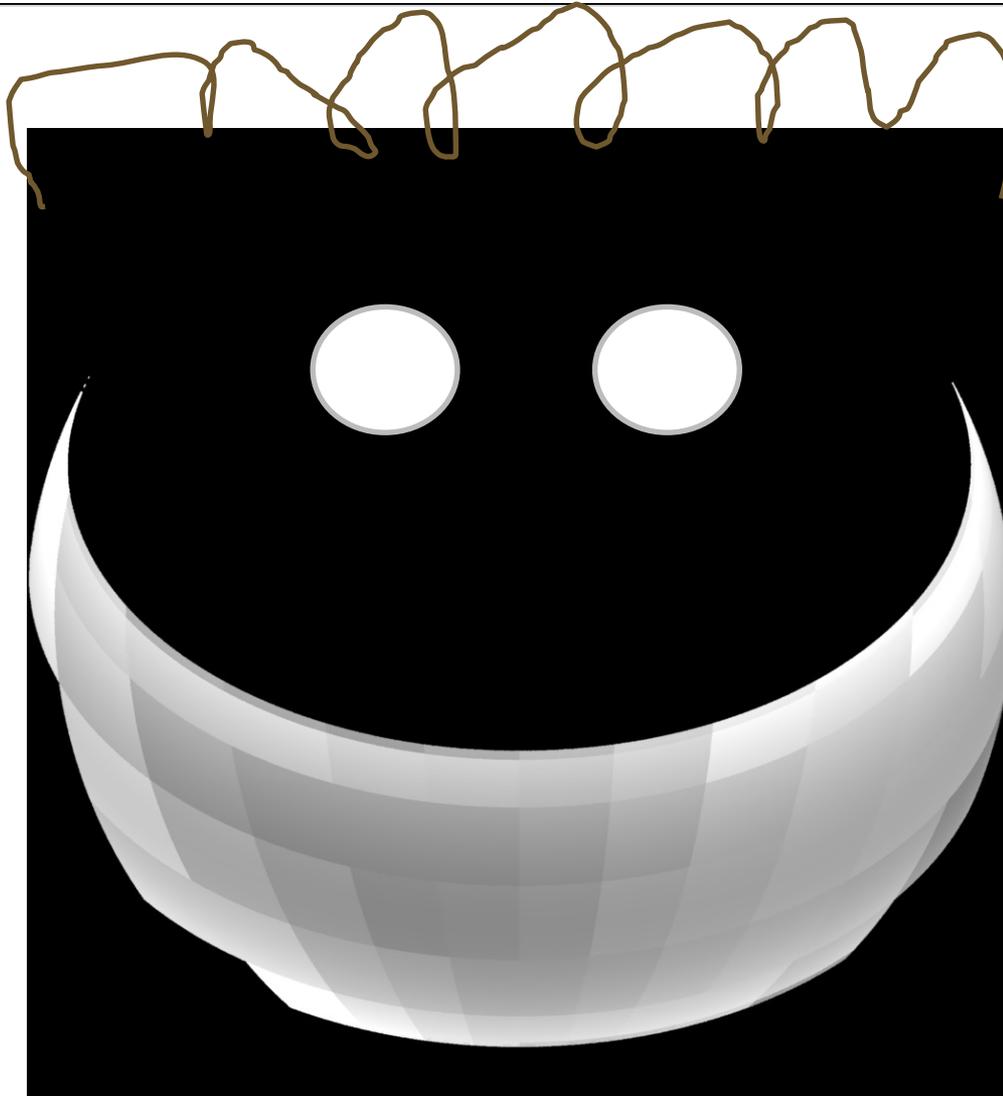


New Cumulative sky generator – WEA_gensky.py



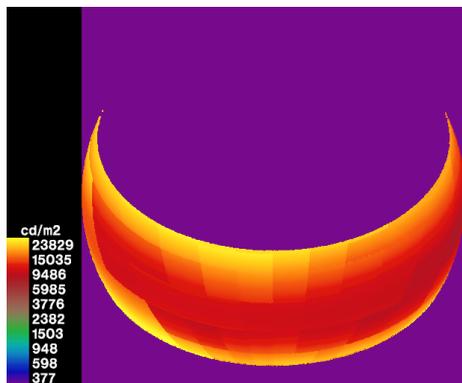


Sunband Weighted by Cloud Cover

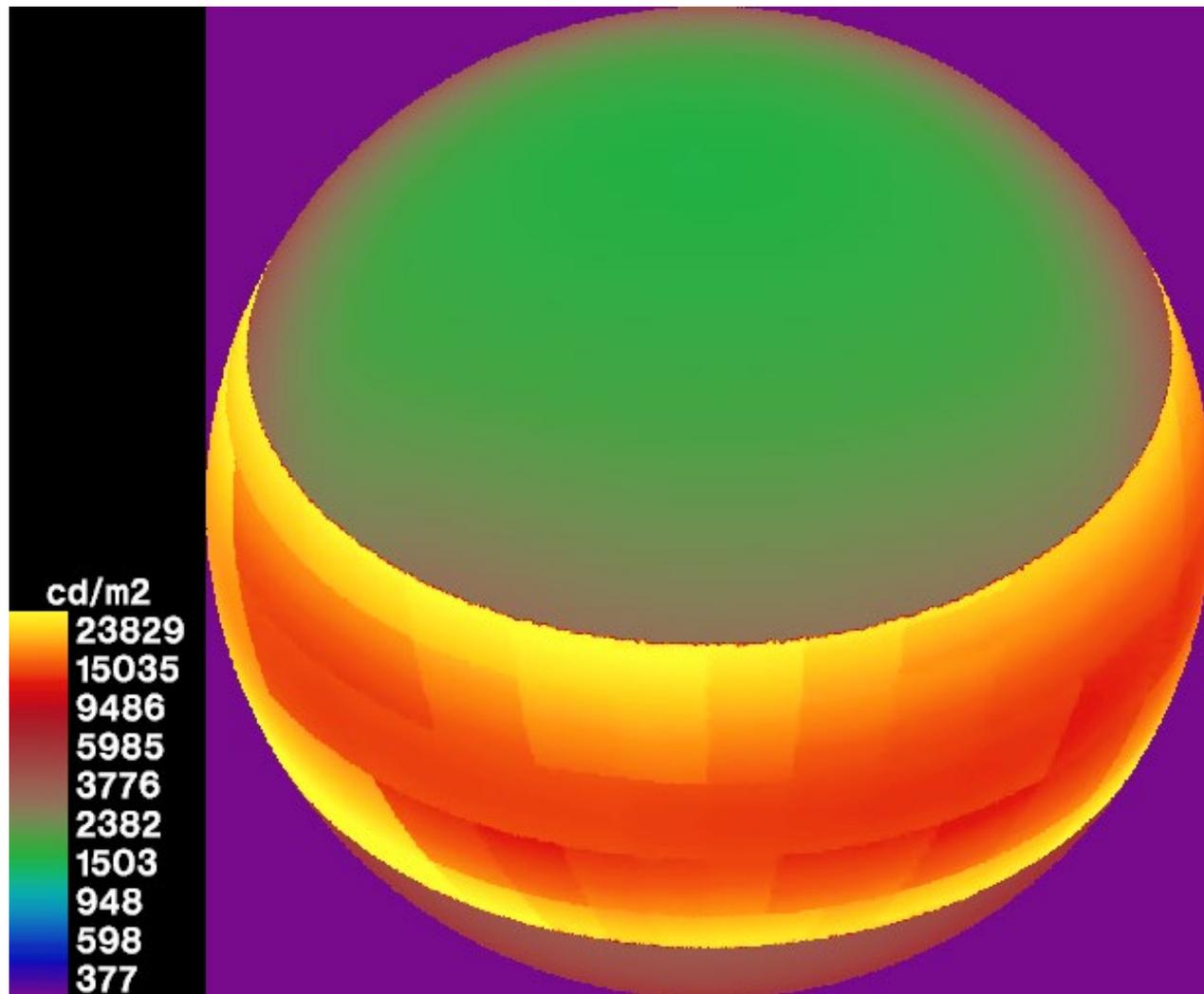
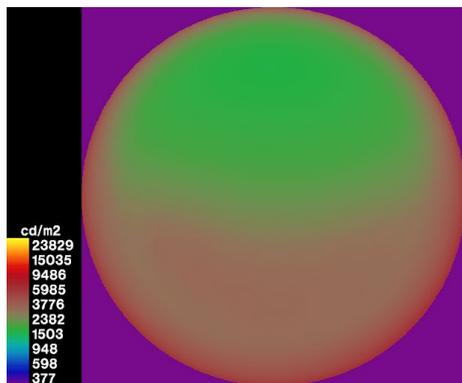




Final Annual Sky and Sunband combined

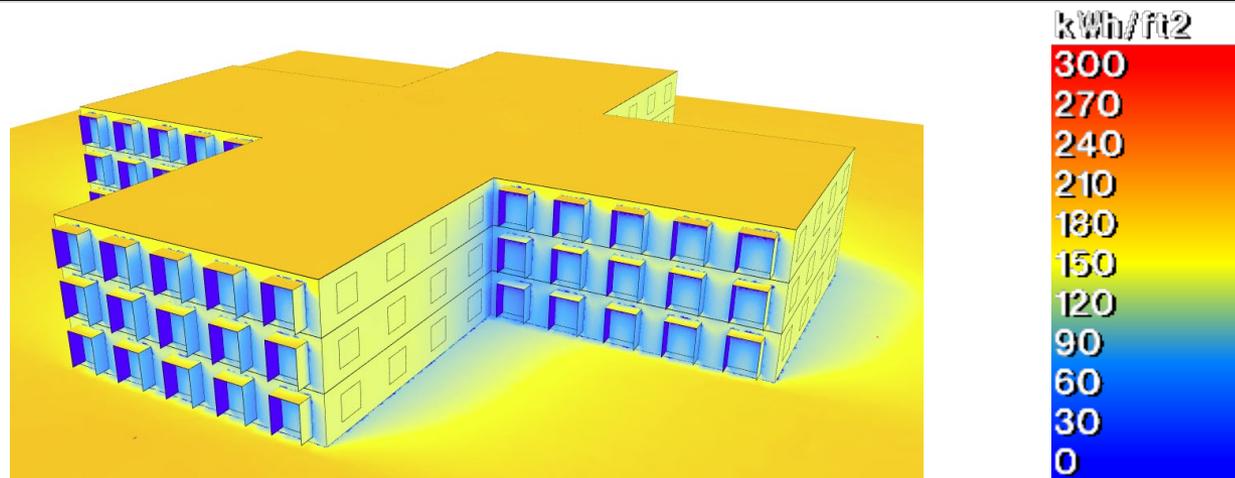


+

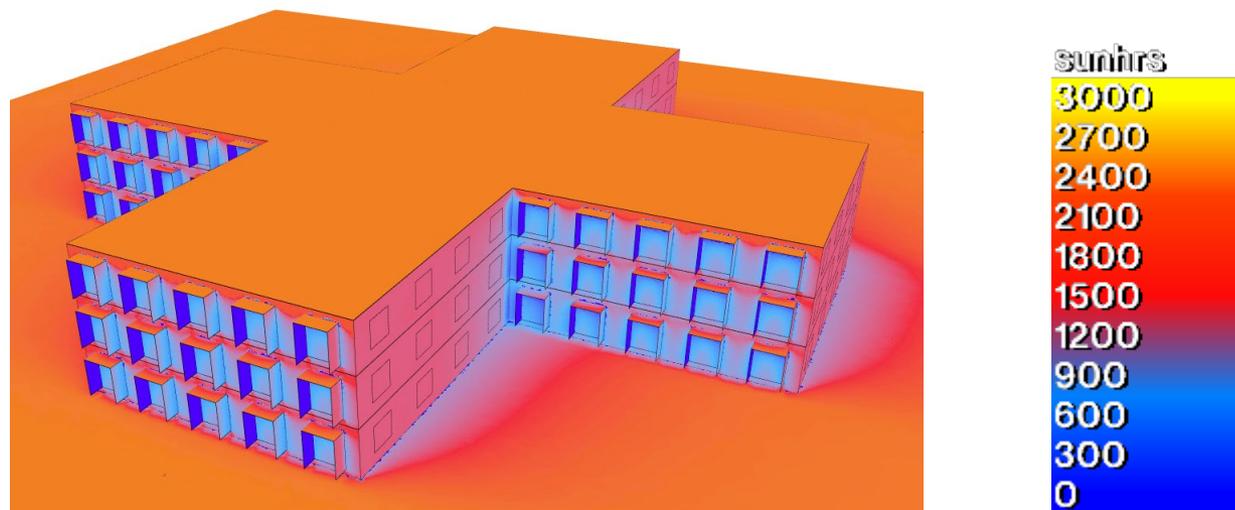




Dynamic 3d implementation with new color maps



Solar radiation with 'cool 2 hot' color map



Effective sunhours with 'sunhr' color map



IESNA Daylight Modeling and Simulation Standards

- Daylight Modeling and Simulation Task Group
 - Task group for the larger IESNA Daylighting Metrics committee
 - Focused on modeling and simulation methods and standards
 - Goal to release a Technical Memorandum (TM-XX) in Spring 2020
 - Overall outline and gold standards
 - With areas of assumption needing further research highlighted
 - Continued development through 2020-2021 with interim Committee Reports (CR) as necessary
 - Ultimately developed into an IESNA Lighting Practice (LP-XX) document
-



IESNA Daylight Modeling and Simulation standards

1. Purpose/Background
 2. Daylight Modeling Methods and Standards
 - i. Sun and Sky Models
 - ii. Surface and Material Modeling
 - iii. Site and Surroundings
 - iv. Fenestration and Window Treatments
 - v. Interior geometry
 3. Simulation for Daylight Sufficiency – Methods and Standards
 - i. Shading control simulation standards
 - ii. Periodic simulation methods
 - iii. Simulation settings
 - iv. Daylight responsive electric lighting control
 - v. Simulation output standards
 - vi. Daylight sufficiency metrics
 - vii. Whole building energy predictions
 - viii. Simulation for plants / animals / artwork preservation
-



IESNA Daylight Modeling and Simulation standards

4. Simulation for Daylight Quality – Methods and Standards

- i. Representative time and daylight condition standards
- ii. Spatial and orientation standards
- iii. Simulation setting adjustments
- iv. Glare analysis methods and standards
- v. Circadian Rhythm Simulation

5. Test Cases

- i. Test Case Geometry
 - ii. Sufficiency test cases
 - iii. Whole building energy test cases
 - iv. Qualitative test cases
-

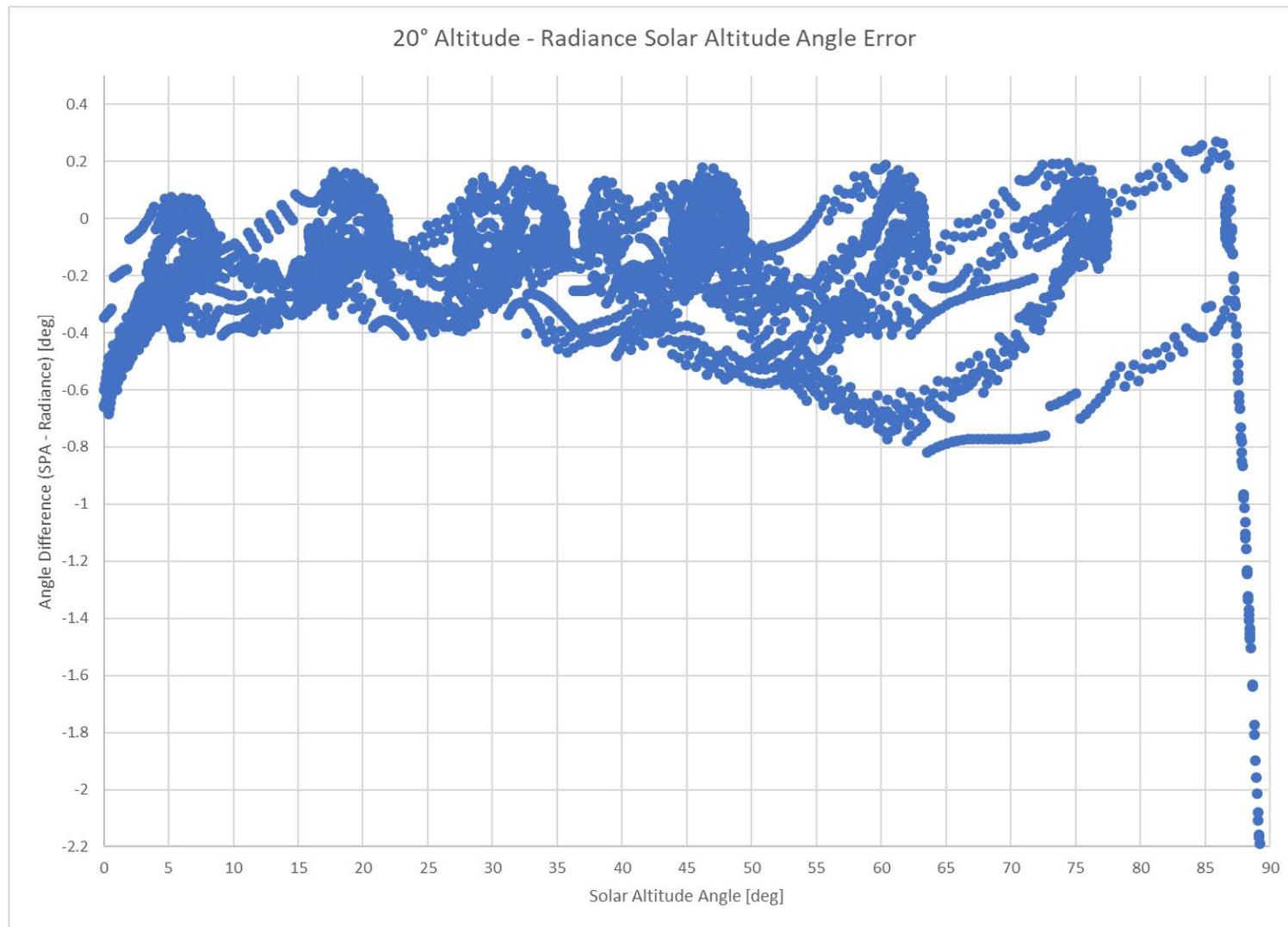


NREL Solar Position Algorithm vs Radiance Solar

- Comparison of NREL's Solar Position Algorithm vs. the Spencer-Moon equations in Radiance
 - Good news – altitude angles and azimuth angles are largely within +/- 1° - likely very little impact on daytime calculations
 - Less good news – possible bigger impact on the number of annual daylight hours
 - 20° lat – 4,436 (SPA) vs 4,414 (Rad) daylight hrs – 22 hrs lost!
 - 40° lat – 4,428 (SPA) vs 4,388 (Rad) daylight hrs – 40 hrs lost!
 - 60° lat – 4,478 (SPA) vs 4,394 (Rad) daylight hrs – 84 hrs lost!
 - Daytime hours are not always ½ of 8760 or 4380 due to refraction from the atmosphere – places on article circle have most (4,647hrs)
 - What to do? Update radiance code with year input that turns on SPA
-

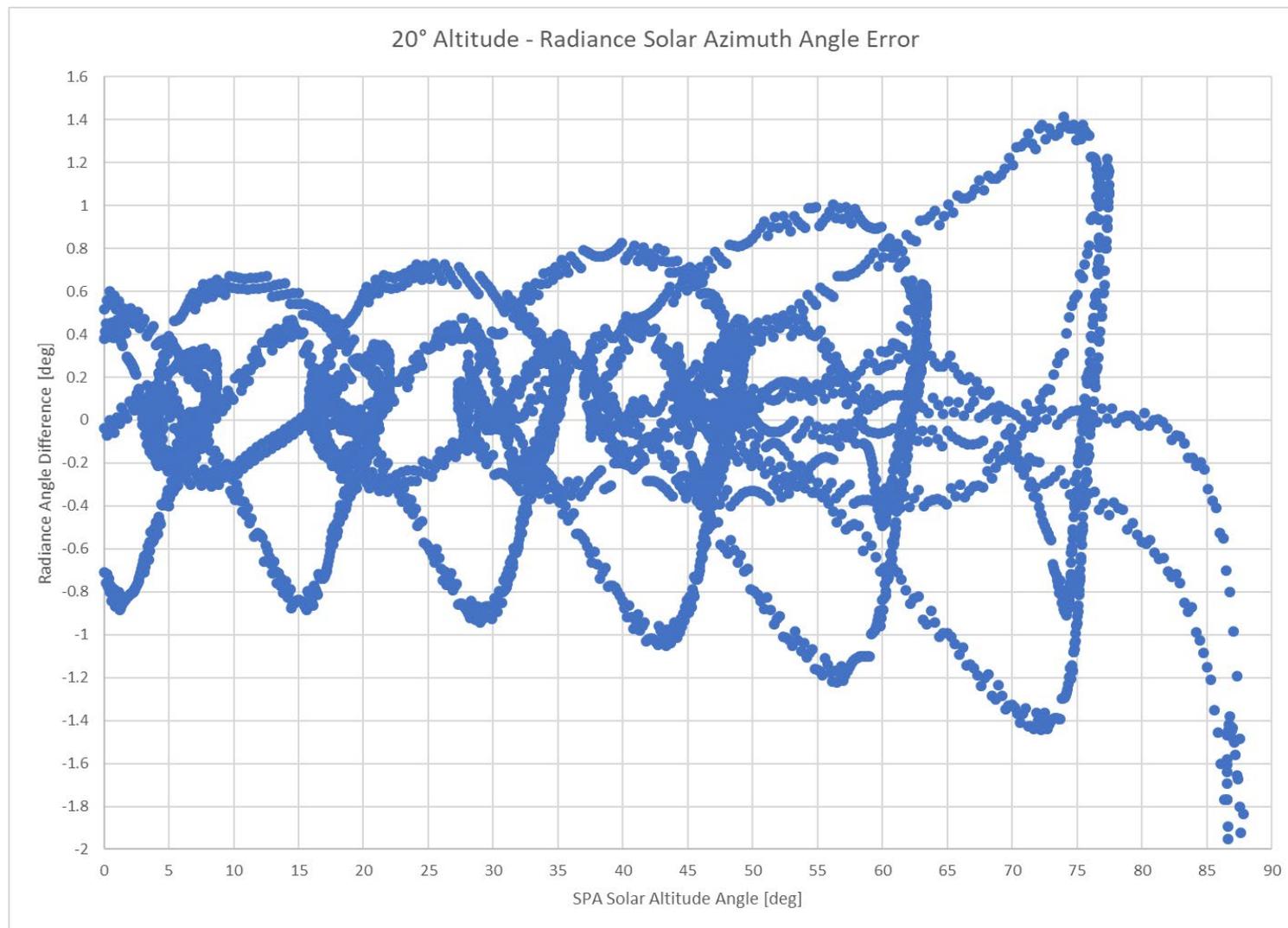


20° Latitude Altitude Angle Error – 22 lost hours



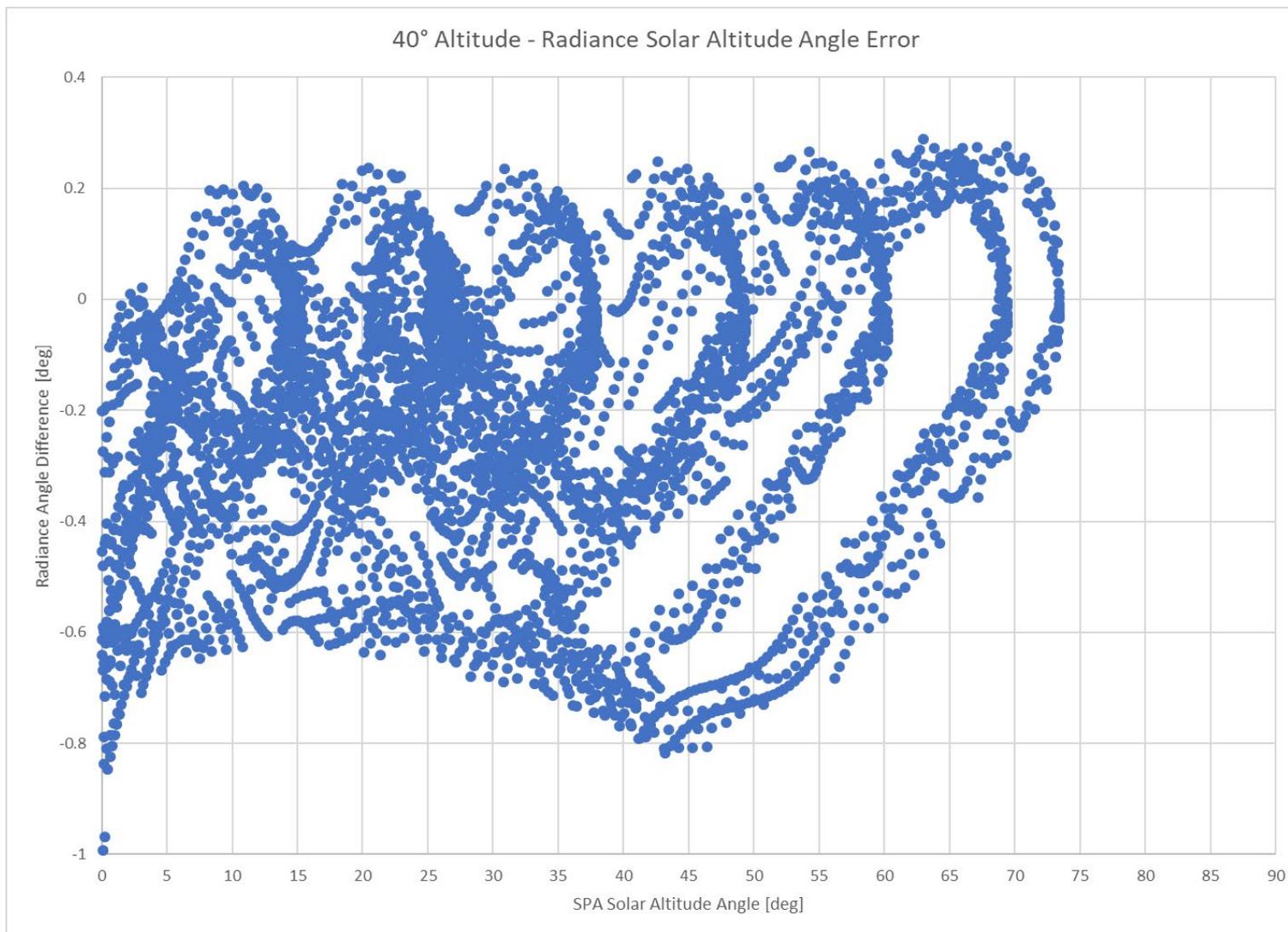


20° Latitude Azimuth Angle Error – 22 lost hours



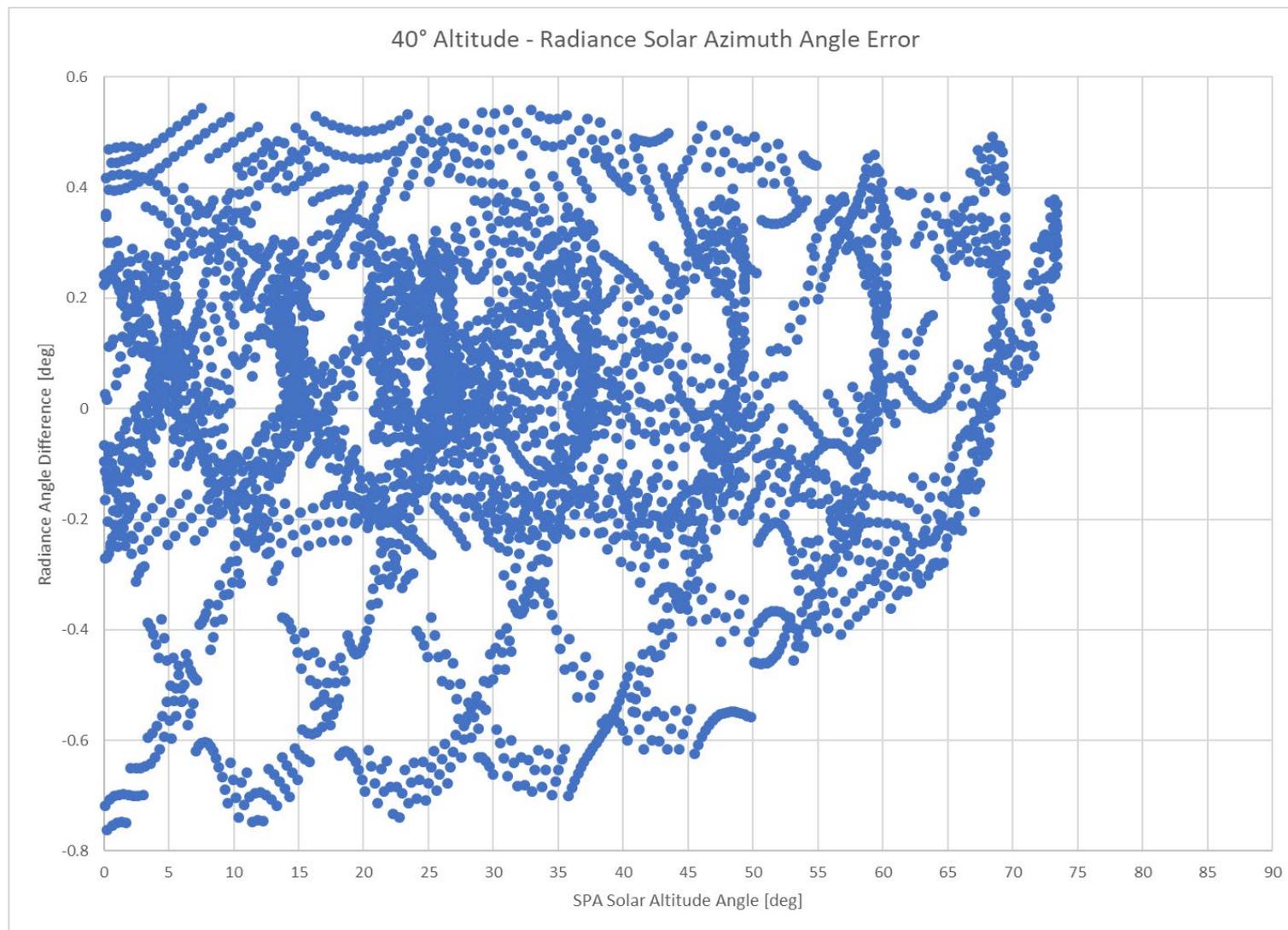


40° Latitude Altitude Angle Error



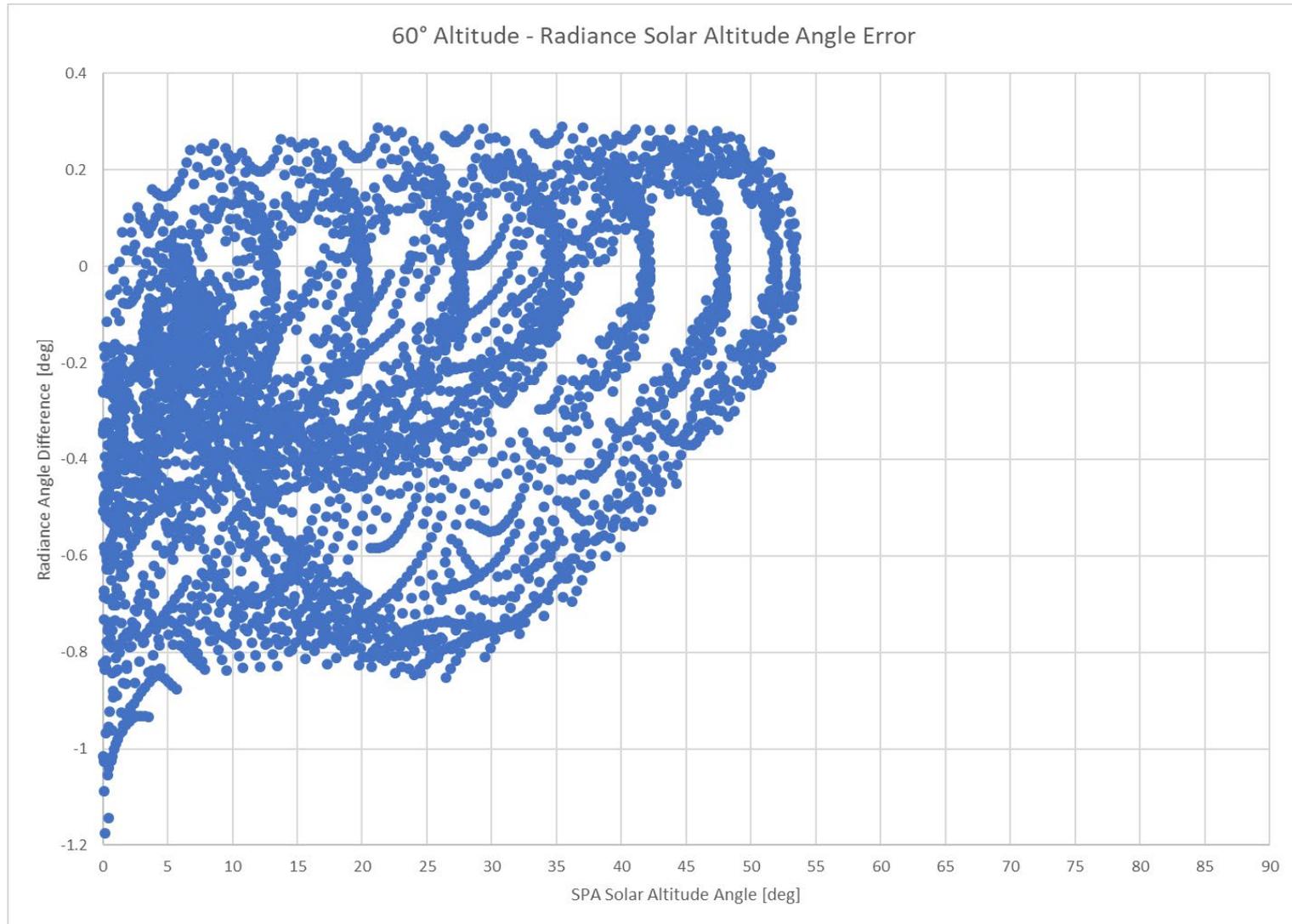


40° Latitude Azimuth Angle Error



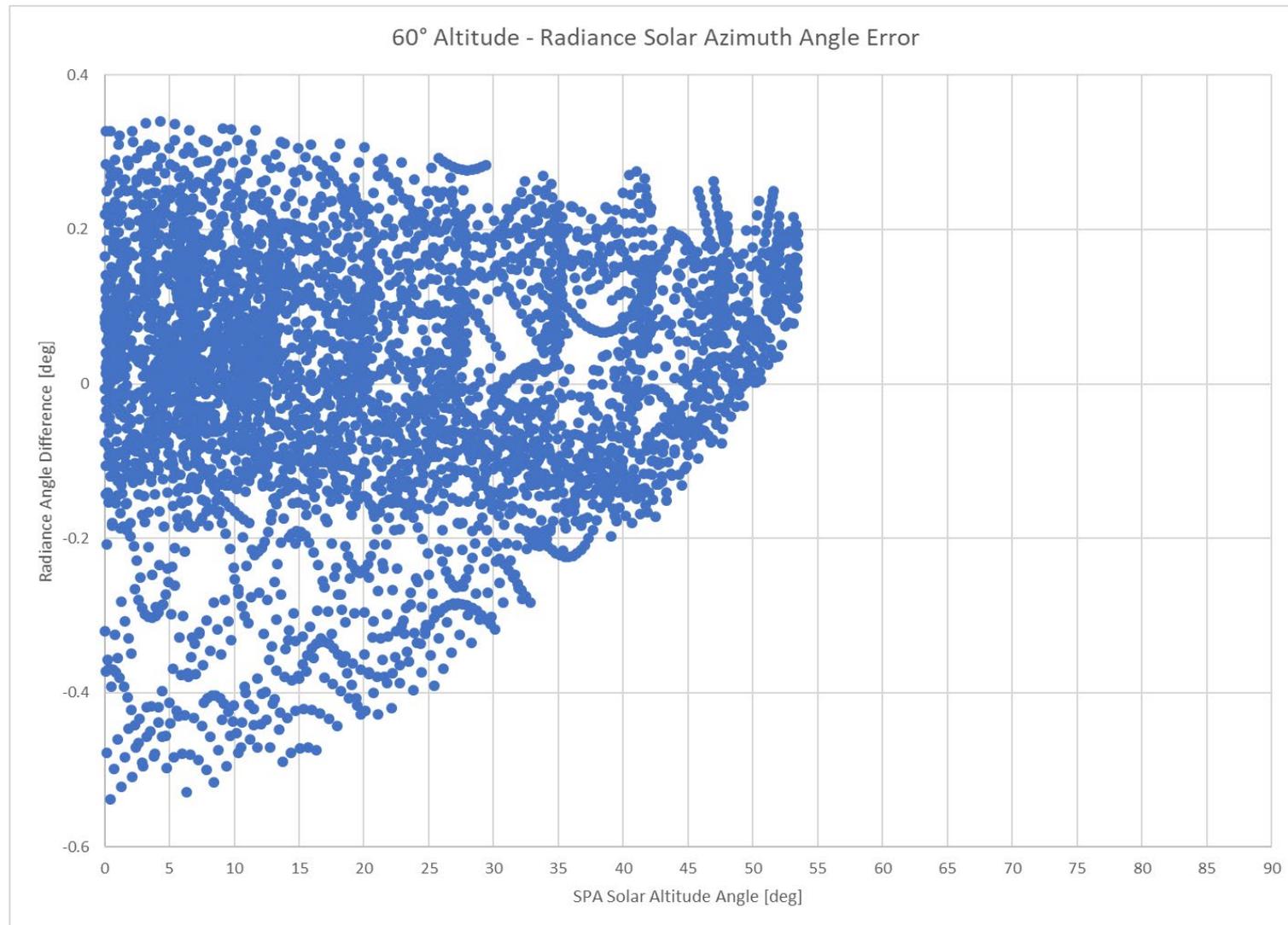


60° Latitude Altitude Angle Error





60° Latitude Azimuth Angle Error



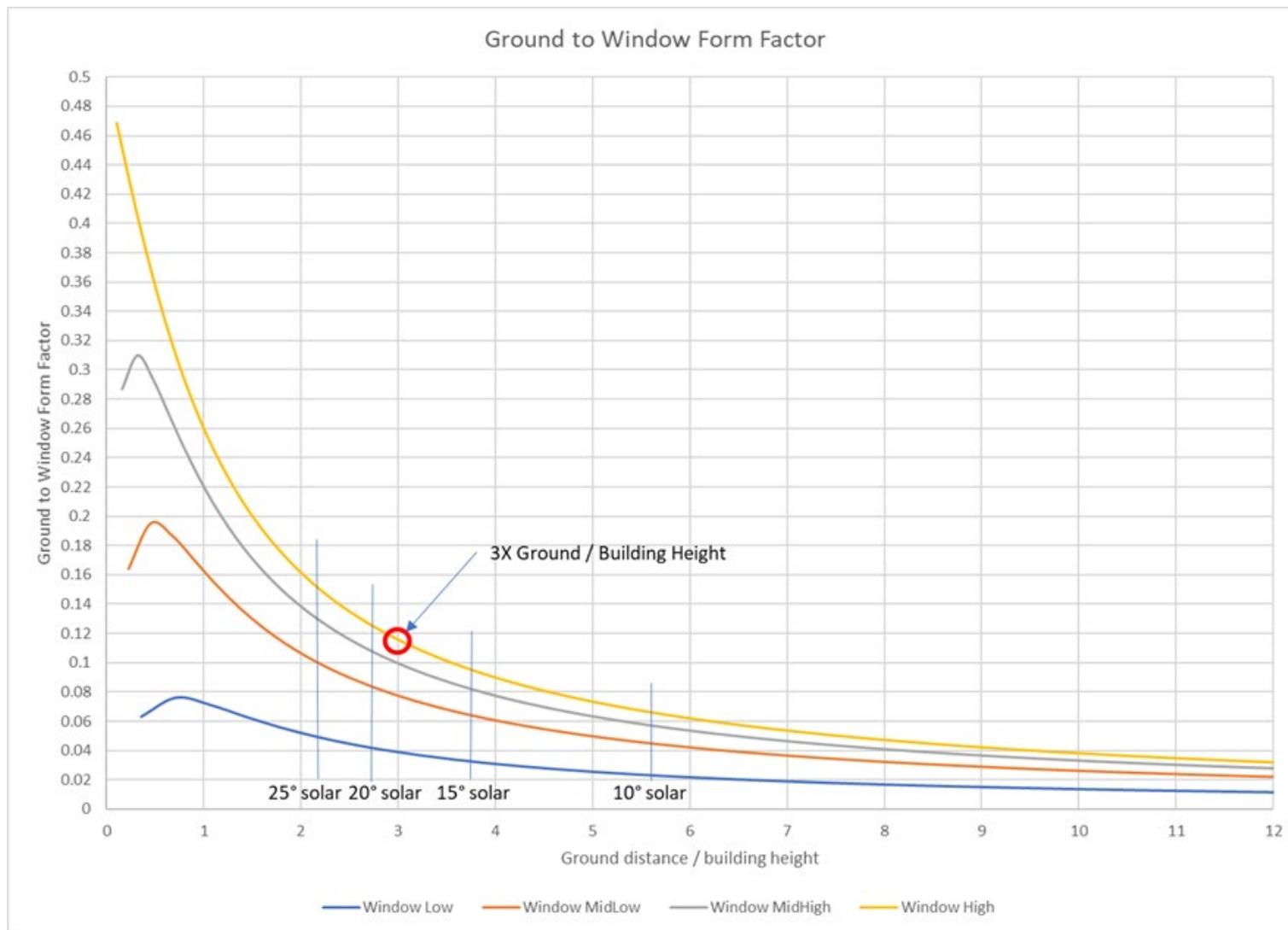


Perez Sky Efficiency and Dew Point Temperature

- Weather files often provide both Radiometric and Photometric data
 - Photometric data often derived from Radiometric using Perez efficacy functions which include dew point temperature adjustments
 - Gendaylit currently applies Perez efficacy functions to radiometric data but defaults to a constant dew point modifier that 'works well for Freiburg'
- Quick impact study on Boulder weather
 - Radiometric data and solar spectrum: Annual - 499kWh/m², Day – 180Wh/m²
 - Photometric data and solar spectrum: Annual - 455kWh/m², Day – 146Wh/m²
 - Using visual spectrum
 - Radiometric annual – 355kWh/m² or 14289 avg lux
 - Photometric annual – 345kWh/m² or 13915 avg lux
- Good news! – not a huge annual error (~3% visual - ~10% solar)
- Worse news! – single day check saw a solar error of 23%
- Where to go?
 - Useradiometric data and -O 1 for solar
 - Use photometric data and -O 0 for visual
 - Hardcode -O options to data type options in gendaylit?
 - Add -td option to gendaylit and see if these conversion errors go down



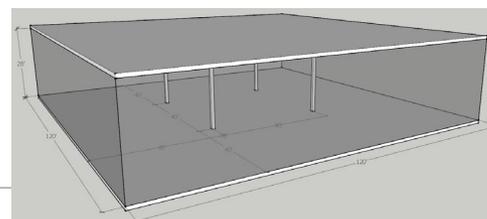
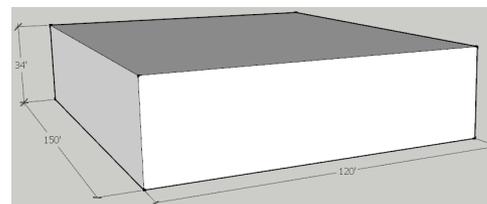
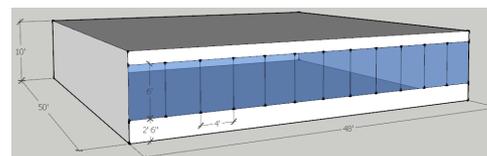
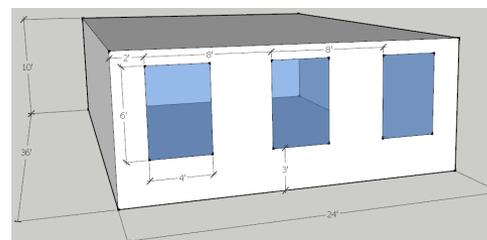
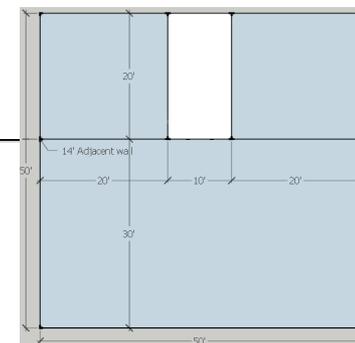
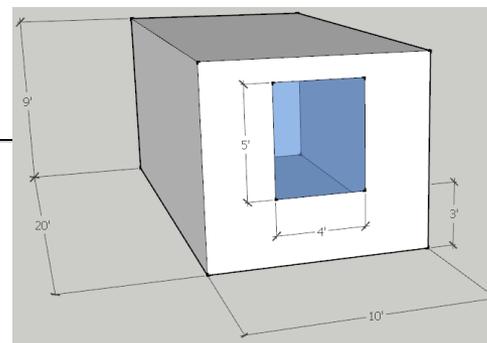
Extents of ground





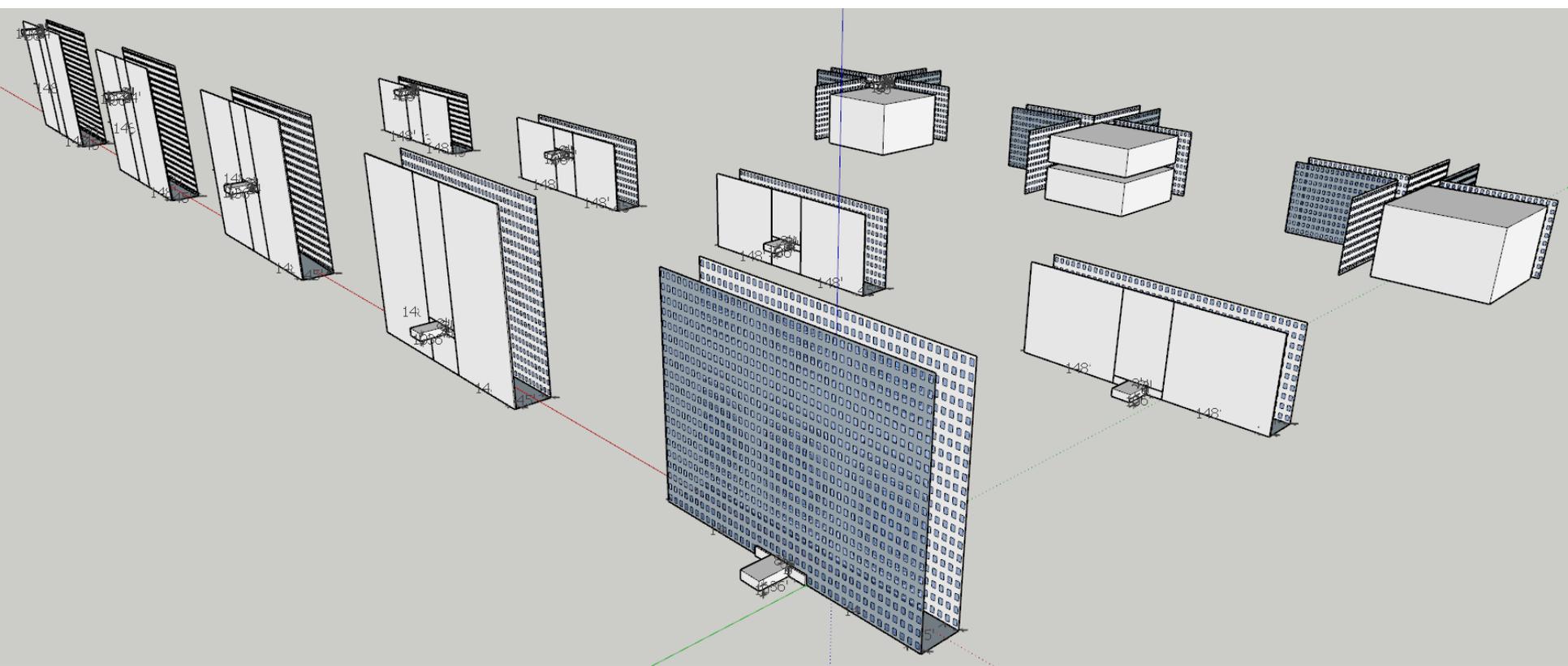
Test Cases - Basic

- Small room
 - Represents single office, conf room, dorm room, break room residential spaces...
- Medium room
 - Represents classroom, shared office, mid-size conf rooms, retail space..
- Large room
 - Open offices, restaurants, retail/strip mall storefronts...
- High-bay space
 - Represents gymnasium, commons/atrium, media centers, large conf rooms...
- Warehouse space
 - Represents warehouses, big-box retail, conf floors...
- Atrium space – not shown



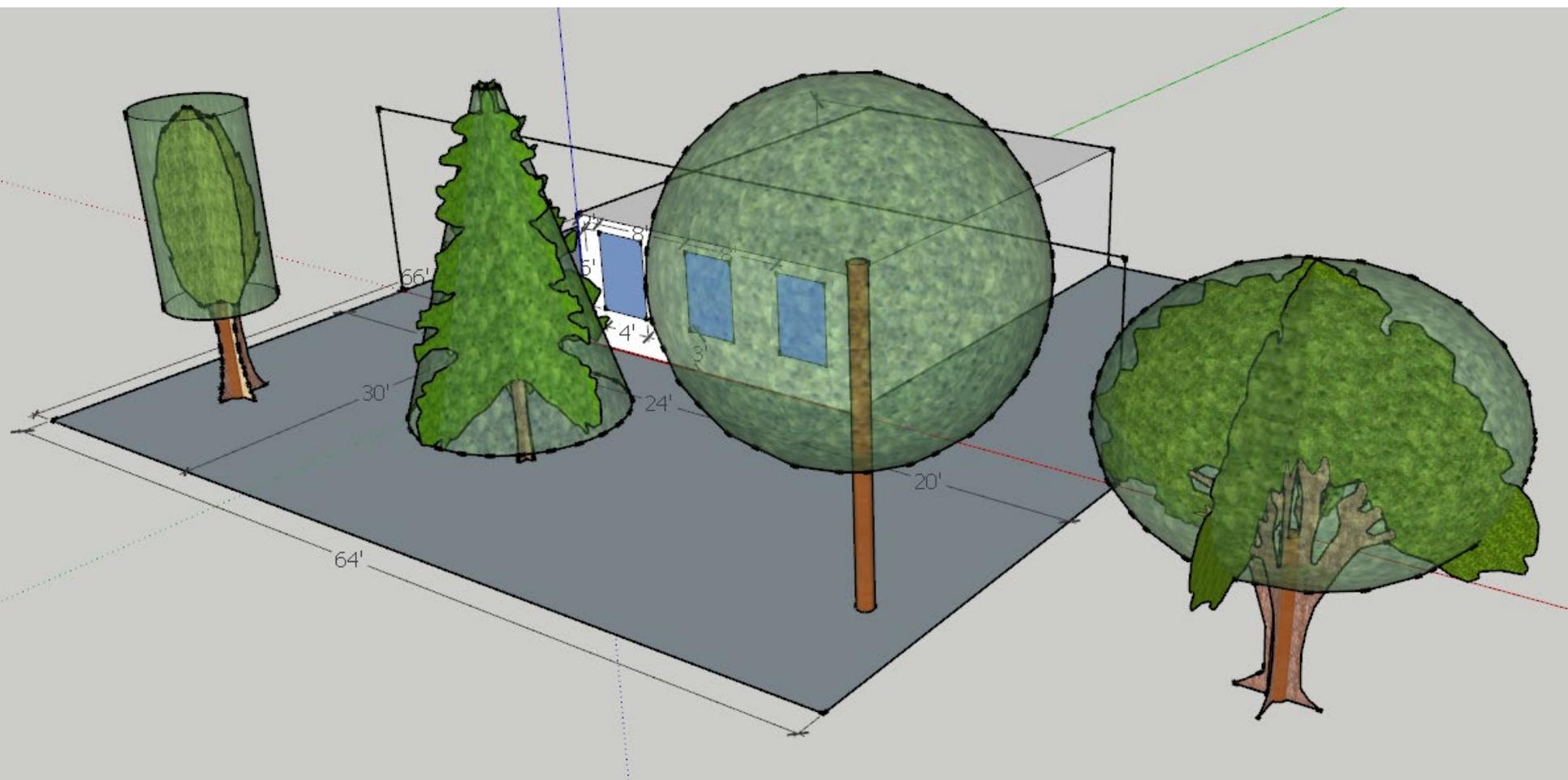


Test Cases – urban surroundings





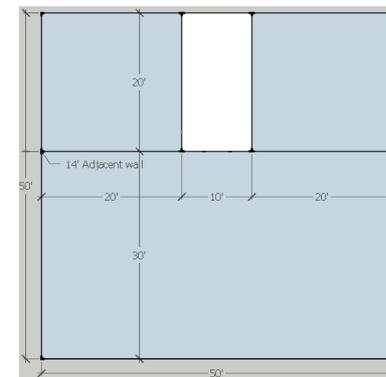
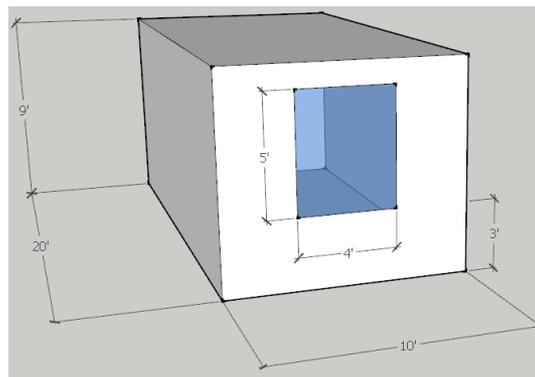
Test Cases – trees / vegetation





Gold Standards Simulations

- `AnnualBruteForce.py --rad Radfile --wea EPWfile [--wdm W|G|L|E] --opt Optfile [--mat MatFile] --pts PtsFile [--rot RotDeg] [--genc] [--skyc "r g b"] [--grndc "r g b"] [--snow]`
- Script reads in a weather file, radiance file, and a pts file and simply runs every daylight hour
- Parallel processing built-in
- Small room timing:
 - ~2days on 8 core-machine
 - ~4hrs on 96 core-machine
- Simulation will be run with and without window treatments
- Annual summary data, annual illum file will be provided as gold standard
- An annual comparison tool will be developed with gold standards loaded



13	20	21	21	21	21	20	20
12	21	22	22	22	22	22	21
11	23	24	24	24	24	24	24
10	26	27	27	27	28	27	27
9	30	31	101	100	100	31	31
8	35	35	105	105	105	36	36
7	81	40	110	110	111	41	97
6	86	88	117	118	119	104	102
5	91	96	127	130	128	112	109
4	98	106	183	143	199	122	115
3	174	309	320	282	334	208	194
2	176	322	416	410	434	222	228
	2	3	4	5	6	7	8

13	6	6	6	6	6	6	6
12	6	6	6	6	6	6	6
11	6	6	6	6	6	6	6
10	6	6	6	6	6	6	6
9	6	6	8	8	8	6	6
8	6	7	9	9	9	6	6
7	8	7	9	9	9	7	9
6	9	9	10	11	10	10	9
5	10	10	12	12	12	11	10
4	11	12	15	14	16	13	12
3	14	20	22	22	23	17	15
2	15	22	29	30	29	20	17
	2	3	4	5	6	7	8

13	7	7	7	7	7	7	7
12	7	8	8	8	8	8	7
11	8	8	9	9	9	8	8
10	9	10	10	10	12	10	9
9	10	11	13	13	13	11	10
8	12	13	16	16	16	13	12
7	16	15	18	19	18	16	16
6	18	21	23	23	23	21	19
5	22	26	28	30	29	26	23
4	27	33	40	39	40	33	27
3	33	48	56	58	56	45	34
2	36	60	78	84	79	56	37
	2	3	4	5	6	7	8



School Studies

- MLK Jr - 360 cafeteria remodel
 - Jones K-12 - new school classroom wing
 - Vanderbilt Univ School of Nursing – Wellness melanopic lux calcs
 - Hillwood HS – gym studies and passive classroom wings
 - Robeson HS – classroom wing and gym revit vs radiance comparisons
-



MLK Jr HS – Cafeteria remodel





MLK Jr HS – Cafeteria remodel





Jones County K-12 School



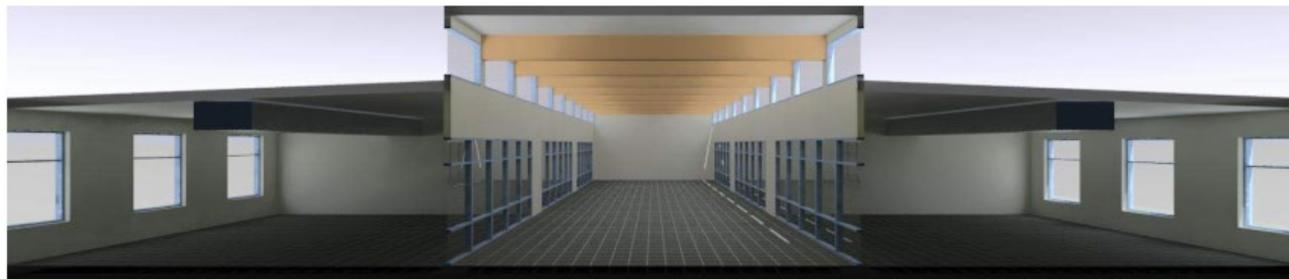
West Classroom Section View



Central Commons Perspective View



East Classroom Perspective View



Classroom Wing Section View - Sunny Equinox, 12pm



Jones County K-12 School

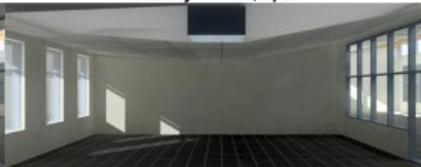
Sunny Fall/Spring, 9am



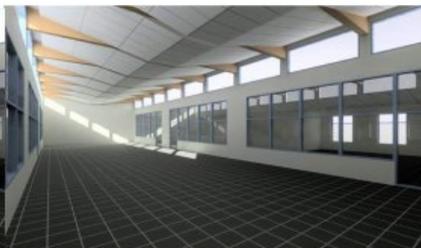
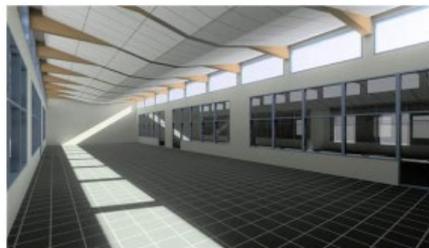
Sunny Fall/Spring, 12pm



Sunny Winter, 3pm



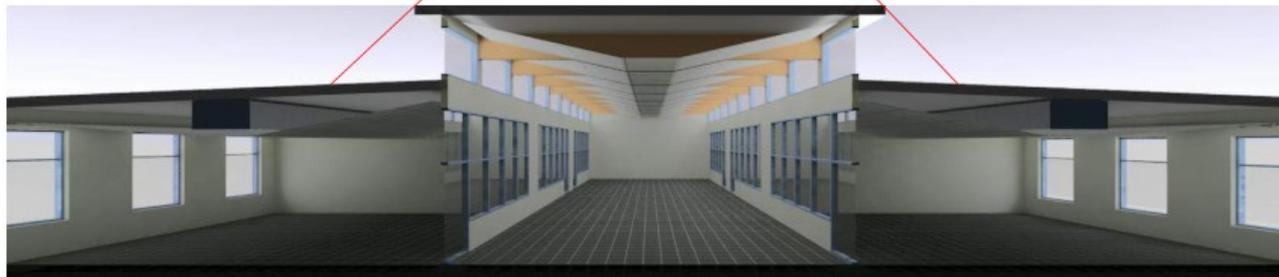
West Classroom Section View



Central Commons Perspective View



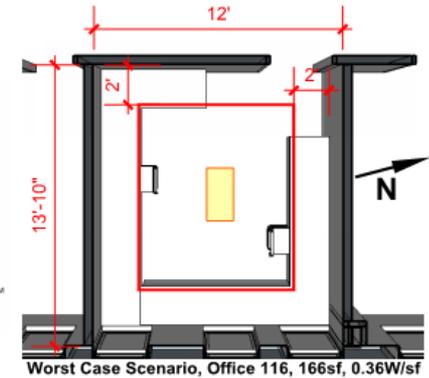
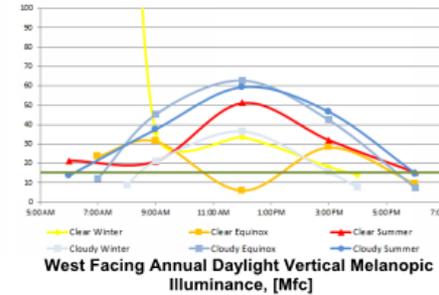
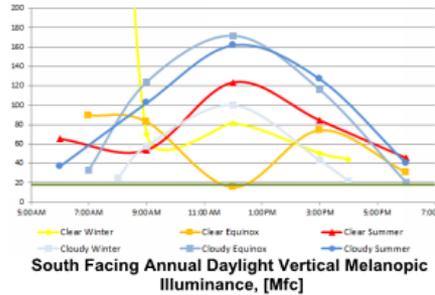
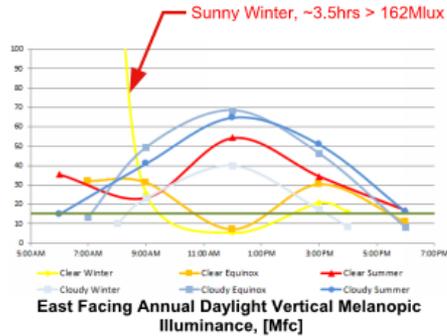
East Classroom Perspective View



Classroom Wing Section View - Sunny Equinox, 12pm



Vanderbilt School of Nursing - Wellness Calcs



	57	98	207	93	72	82	79	65	58	62	62	52
11	98	207	93	207	91	187	90	145	103	103	145	90
	206	238	77	271	298	309	298	271	237	237	206	206
10	64	69	74	72	68	63	62	61	58	58	61	58
	205	239	278	307	320	309	277	238	202	202	238	202
9	69	69	70	70	68	65	64	62	63	63	62	63
	113	277	103	283	97	257	92	189	114	114	189	92
8	186	218	252	280	291	280	251	214	183	183	214	183
	73	70	70	69	68	67	66	65	68	68	65	68
7	118	300	107	315	99	290	93	211	120	120	211	93
	151	170	196	218	225	216	195	169	147	147	169	147
6	88	88	92	95	96	93	90	84	82	82	84	82
	120	314	108	330	99	305	93	219	120	120	219	93
5	115	125	138	150	154	149	135	122	113	113	122	113
	115	125	138	150	154	149	135	122	113	113	122	113
4	118	310	106	325	98	300	92	215	121	121	215	92
	88	88	92	95	96	93	90	84	82	82	84	82
3	151	170	196	218	225	216	195	169	147	147	169	147
	113	287	102	297	94	271	90	200	117	117	200	90
2	73	70	70	69	68	67	66	65	68	68	65	68
	186	218	252	280	291	280	251	214	183	183	214	183
1	105	254	95	257	90	234	87	178	108	108	178	87
	69	69	70	70	68	65	64	62	63	63	62	63
	205	239	278	307	320	309	277	238	202	202	238	202
0	95	216	87	215	84	192	84	151	101	101	151	84
	64	69	74	72	68	63	62	61	58	58	61	58
	206	238	271	298	309	298	271	237	206	206	237	206
0	83	182	77	176	79	157	83	128	98	98	128	83
	57	72	82	72	68	65	62	62	52	52	62	52
	2	3	4	5	6	7	8	9	10			
	Electric Lighting Vertical Melanopic Illuminance [Mlux]											

	169	179	190	203	217	225	224	216	208	
11	150	237	165	248	177	250	260	240	268	
	423	468	492	686	687	658	536	561	488	
10	164	171	180	190	198	202	203	200	197	
	158	250	174	261	189	261	272	252	280	
	471	511	539	751	747	535	590	615	710	
9	160	165	172	178	184	187	189	188	185	
	172	269	187	273	203	278	286	277	295	
	513	562	592	820	809	652	652	615	773	
8	159	162	166	171	175	177	178	179	178	
	188	294	210	291	301	296	312	300	279	
	589	628	823	880	760	725	682	703	852	
7	160	161	163	167	170	172	172	174	175	
	210	313	240	316	333	320	344	329	308	
	669	709	897	969	853	859	787	982	947	
6	162	162	163	166	168	169	171	173	176	
	239	339	356	352	376	371	421	373	338	
	758	990	998	1107	951	919	901	1097	1113	
5	167	166	166	167	169	170	173	176	181	
	301	347	436	391	499	406	395	522	374	
	954	1173	1233	1035	997	1065	1299	1300	1251	
4	175	171	171	176	174	176	179	184	191	
	372	363	530	387	566	475	464	496	380	
	1159	1311	1260	1127	1162	1314	1489	1525	1273	
3	185	181	179	180	180	183	188	194	205	
	559	357	715	436	608	521	486	613	387	
	1618	1506	1152	1162	1378	1564	1765	1679	1534	
2	199	192	189	189	190	194	198	208	224	
	802	347	957	396	741	580	495	744	365	
	2148	1625	1065	1190	1739	2197	2037	1640	1846	
	2	3	4	5	6	7	8	9	10	
	Annual Average Daylight Vertical Melanopic Illuminance [Mlux]									

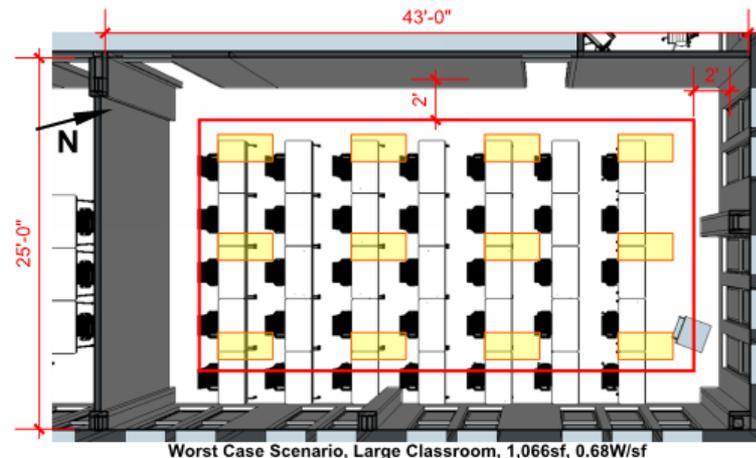
	259	273	289	305	319	326	322	310	298	
11	248	445	258	454	268	436	349	385	371	
	629	706	763	984	996	957	808	798	694	
10	252	261	272	284	293	296	295	290	285	
	264	490	272	503	282	480	362	415	388	
	676	750	817	1058	1068	844	867	853	913	
9	249	254	261	268	274	277	277	275	273	
	285	543	290	555	300	533	378	463	409	
	698	780	845	1101	1100	933	903	829	956	
8	250	252	260	267	271	273	273	269	269	
	306	597	317	605	400	584	405	509	399	
	740	798	1018	1098	985	941	877	872	999	
7	273	280	292	302	308	307	299	291	287	
	330	625	348	646	431	621	438	548	428	
	785	834	1035	1119	1007	1008	922	1104	1060	
6	306	321	344	363	370	365	349	333	319	
	357	643	462	675	474	665	513	583	459	
	846	1078	1090	1202	1047	1012	990	1181	1195	
5	346	371	403	431	443	432	411	381	358	
	414	634	538	686	593	675	485	715	491	
	1027	1243	1303	1104	1065	1132	1364	1365	1318	
4	381	412	449	488	497	486	458	423	395	
	477	618	625	644	656	705	551	664	488	
	1227	1379	1330	1197	1230	1379	1552	1587	1335	
3	400	430	467	496	507	499	472	442	419	
	654	576	802	652	692	714	570	756	488	
	1682	1573	1226	1234	1446	1627	1828	1736	1592	
2	408	430	458	481	491	485	467	446	431	
	885	536	1035	579	819	739	578	863	463	
	2205	1697	1147	1269	1804	2256	2099	1701	1898	
	2	3	4	5	6	7	8	9	10	
	Annual Average Combined Vertical Melanopic Illuminance [Mlux]									



Vanderbilt School of Nursing - Wellness Calcs

	193	237	255	251	265	278	264	264	277	263	246	248	227	182														
	195	428	187	404	323	332	386	412	320	445	350	332	448	371	379	438	340	338	451	304	415	366	330	293	402	147	422	128
	340	476	507	453	504	553	484	481	553	499	443	494	456	298														
	222	274	287	270	293	318	284	286	318	291	264	278	257	183														
7	219	507	189	469	368	358	451	471	348	523	392	363	525	415	422	515	366	374	528	330	474	425	358	338	469	135	502	118
	283	328	345	350	368	381	366	368	376	361	343	335	309	245														
	311	425	451	402	448	492	430	430	492	445	397	440	404	266														
	228	489	196	445	338	368	430	469	353	489	374	361	497	417	428	484	368	356	494	332	471	402	368	304	443	149	489	154
	330	425	456	425	463	497	453	451	494	456	417	443	412	314														
6	288	340	325	363	361	381	394	379	376	392	374	353	350	323	269													
	234	523	200	479	371	376	461	492	363	533	394	376	535	433	443	523	381	376	535	340	494	430	379	332	476	153	520	187
	307	412	438	389	435	476	415	415	476	415	476	433	422	386	264													
5	332	440	463	417	463	510	445	445	507	461	412	453	422	295														
	232	520	197	476	366	374	458	489	361	530	394	371	533	430	440	520	379	376	535	338	492	430	374	330	476	138	517	118
	261	306	325	323	343	356	340	340	340	353	340	318	316	288	223													
4	345	448	479	448	487	520	476	476	517	481	440	466	428	306														
	222	481	188	435	327	358	420	458	345	479	361	350	487	407	417	476	358	348	484	322	463	394	361	292	435	130	479	108
	274	381	407	356	399	445	381	384	445	402	353	397	368	246														
3	297	343	368	368	386	397	386	394	381	358	350	320	255															
	207	487	175	458	350	340	435	451	332	510	366	345	507	392	404	497	345	366	510	309	463	407	343	324	451	132	481	111
	170	207	230	207	224	247	227	218	254	241	201	211	203	166														
2	350	487	520	466	520	569	499	499	566	512	458	507	466	320														
	180	384	153	368	275	314	371	363	282	402	298	320	428	324	340	394	293	330	430	273	397	327	297	260	363	136	384	166
	110	121	187	168	141	183	186	140	178	229	131	117	114	147														
	2	3	4	5	6	7	8	9	10																			

Room Width, [ft]
Electric Lighting Vertical Melanopic Illuminance [Mlux]



128	139	152	162	172	184	196	205	223	247	269	310	367	365														
115	213	115	225	125	244	135	260	148	283	157	314	172	337	180	367	193	423	204	486	215	583	242	733	274	1053	327	1713
266	270	325	331	335	386	400	410	441	487	515	591	703	1148														
115	120	129	137	146	157	169	180	200	222	260	319	442	921														
120	220	116	225	128	248	138	274	146	277	160	322	168	348	176	401	193	455	202	551	209	667	233	898	262	1443	302	2480
305	329	378	394	410	432	451	462	510	545	570	609	822	1069														
113	113	119	125	134	147	158	174	195	229	277	364	549	1001														
133	244	129	266	146	277	158	298	168	332	186	365	186	403	201	442	210	530	225	598	232	723	249	894	281	1291	315	1722
367	397	450	477	484	511	528	542	577	606	653	711	866	552														
119	114	118	126	135	146	159	176	204	240	295	383	483	429														
154	278	159	293	181	314	196	341	205	364	223	406	231	433	234	495	249	577	256	657	259	775	281	958	307	1248	359	1092
434	491	549	560	597	606	633	632	647	671	740	852	1109	1195														
131	123	126	130	138	154	168	183	211	245	297	365	434	725														
184	335	199	333	236	357	248	394	255	399	272	440	282	472	283	526	297	607	305	716	289	856	319	1054	357	1475	408	2594
551	637	687	706	732	730	736	743	762	774	836	936	1047	1205														
151	141	142	148	158	169	184	205	230	274	325	400	528	883														
234	410	275	384	361	425	336	463	331	454	362	500	354	556	358	589	382	657	376	600	340	940	382	1093	466	1584	532	2774
738	871	904	915	962	936	938	953	907	894	1010	1110	1175	1301														
184	169	170	177	183	193	212	228	266	300	364	458	616	876														
302	554	424	474	539	532	452	632	446	565	560	574	488	711	456	653	552	639	516	908	372	1002	520	1127	609	1366	661	2494
1127	1374	1170	2450	1442	1283	1268	1415	1240	1083	1410	1629	1445	1050														
241	214	207	214	222	237	248	270	299	344	404	503	643	741														
337	967	897	908	1488	461	342	1084	915	1001	1013	487	389	1128	900	1051	992	473	466	962	483	1156	839	1264	909	1181	974	599
2116	2636	1365	1762	2585	1892	1562	2615	2017	714	2627	2890	2729	985														

Annual Average Daylight Vertical Melanopic Illuminance [Mlux]

323	334	347	356	367	379	391	400	418	441	464	504	561	559														
310	407	310	420	319	439	330	454	343	478	352	509	367	531	375	561	388	617	399	680	410	777	437	928	468	1247	521	1907
461	465	520	526	530	580	594	604	636	681	709	785	897	1343														
309	315	323	332	341	351	363	374	394	417	455	513	636	1116														
315	415	311	422	322	443	332	468	340	471	355	516	363	542	371	595	387	650	396	745	404	862	428	1093	456	1638	496	2674
499	523	572	588	604	626	646	657	704	740	765	804	1016	1263														
308	307	313	320	329	341	353	368	389	424	471	559	743	1196														
328	438	324	460	340	472	353	490	363	527	381	560	380	598	395	636	404	724	419	793	427	918	443	1088	476	1486	509	1916
362	591	644	672	679	706	723	736	772	800	847	906	1061	747														
513	309	312	320	330	340	353	371	399	434	490	578	678	624														
349	473	353	487	375	508	390	535	400	559	417	600	425	627	428	690	443	772	450	852	454	969	475	1153	502	1443	553	1286
628	686	744	754	791	800	827	826	841	866	935	1047	1303	1390														
326	317	321	324	332	348	363	378	405	440	491	560	628	920														
379	530	393	482	430	551	442	588	450	594	467	634	477	667	478	720	492	802	500	911	484	1050	514	1248	552	1669	603	2789
746	831	882	900	927	924	930	937	956	969	1031	1131	1242	1399														
345	336	336	343	353	364	378	399	425	468	520	595	723	1078														
428	605	469	578	555	619	531	658	525	648	556	695	549	751	552	783	577	851	571	995	535	1124	576	1287	661	1778	727	2968
933	1066	1099	1110	1157	1131	1133	1148	1102	1089	1204	1304	1370	1496														
379	364	364	371	377	387	407	422	460	494	558	653	811	1070														
497	748	619	669	734	727	647	826	641	759	754	768	682	906	651	847	746	834	711	1102	566	1197	714	1321	804	1561	855	2689
1321	1569	1365	2644	1636	1477	1463	1610	1434	1278	1605	1823	1640	1245														
435	409	402	409	417	431	443	465	494	538	599	697	838	936														
531	1162	1092	1102	1683	655	537	1278	1110	1196	1208	681	584	1323	1095	1245	418	667	640	1156	677	1350	1034	1458	1103	1375	1168	793
2310	2831	1559	1957	2780	2087	1757	2810	2211	909	2822	3085	2924	1180														



Hillwood HS – Gym Studies



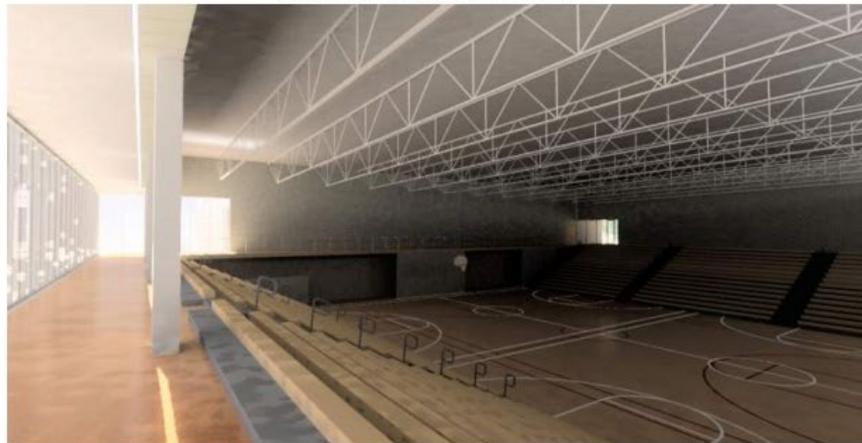
Southwest Perspective, Sunny Equinox at noon



Northwest Perspective, Sunny Equinox at noon



Southeast Perspective, Sunny Equinox at noon



Northeast Perspective, Sunny Equinox at noon



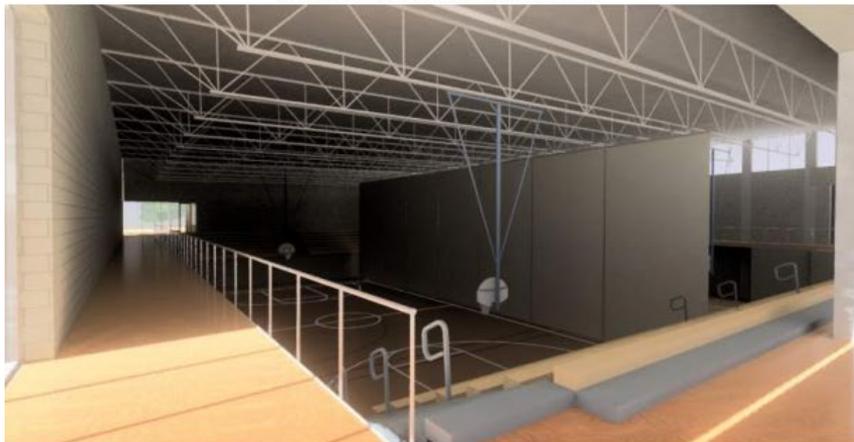
Hillwood HS – Gym Studies



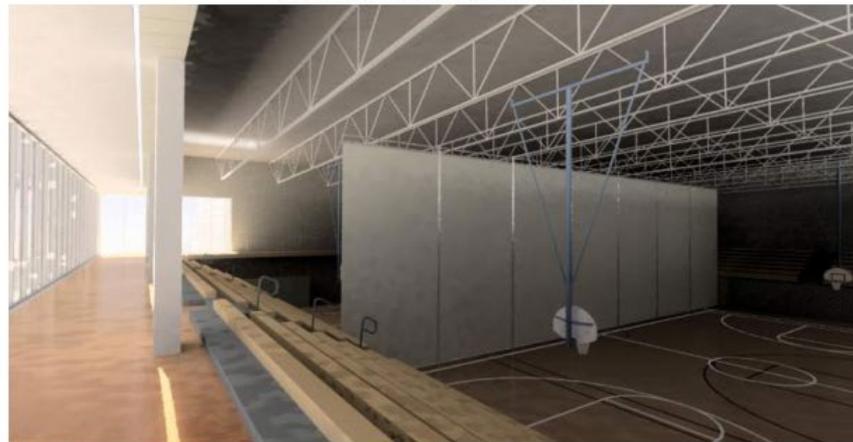
Southwest Perspective, Sunny Equinox at noon



Northwest Perspective, Sunny Equinox at noon



Southeast Perspective, Sunny Equinox at noon



Northeast Perspective, Sunny Equinox at noon



Hillwood HS – Gym Studies



Southwest Perspective, Sunny Equinox at noon



Northwest Perspective, Sunny Equinox at noon



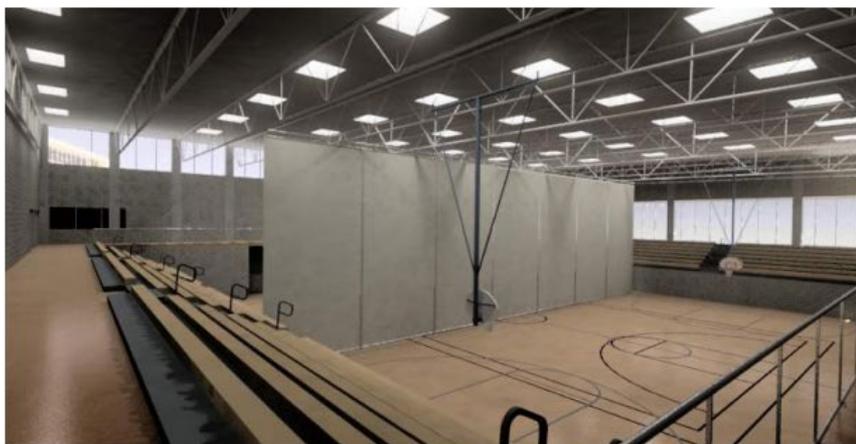
Southeast Perspective, Sunny Equinox at noon



Northeast Perspective, Sunny Equinox at noon



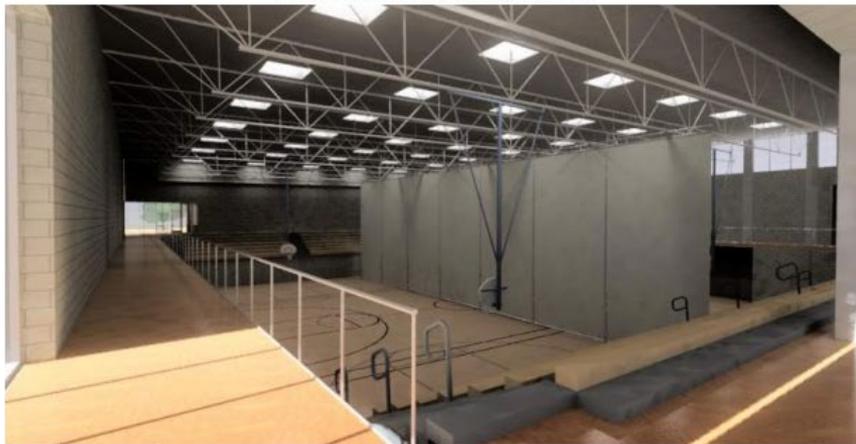
Hillwood HS – Gym Studies



Southwest Perspective, Sunny Equinox at noon



Northwest Perspective, Sunny Equinox at noon



Southeast Perspective, Sunny Equinox at noon



Northeast Perspective, Sunny Equinox at noon



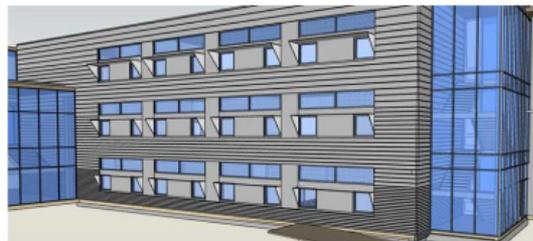
Hillwood HS – passive thermal strategies



South Class - Sunny Equinox, 12pm

23	0.86	0.68	0.69	0.69	0.69	0.69	0.69	0.69	0.68	0.68	0.67	0.65	
20	0.68	0.70	0.71	0.71	0.72	0.72	0.72	0.71	0.71	0.70	0.68		
17	0.70	0.72	0.73	0.74	0.74	0.74	0.74	0.74	0.73	0.73	0.72	0.71	
14	0.73	0.74	0.76	0.76	0.77	0.76	0.76	0.76	0.76	0.75	0.74		
11	0.75	0.77	0.78	0.79	0.79	0.79	0.79	0.79	0.79	0.78	0.77	0.76	
8	0.77	0.79	0.80	0.81	0.81	0.81	0.81	0.81	0.81	0.80	0.80	0.78	
5	0.79	0.81	0.82	0.83	0.83	0.83	0.83	0.83	0.82	0.83	0.82	0.80	
2	0.81	0.86	0.84	0.81	0.85	0.87	0.94	0.86	0.86	0.82	0.81	0.86	0.85
	2	5	8	11	14	17	20	23	26	29	32	35	38

South Class - Annual Daylight Saturation



South Façade - 42%WWRint, 16%WFR, 25%WWRext



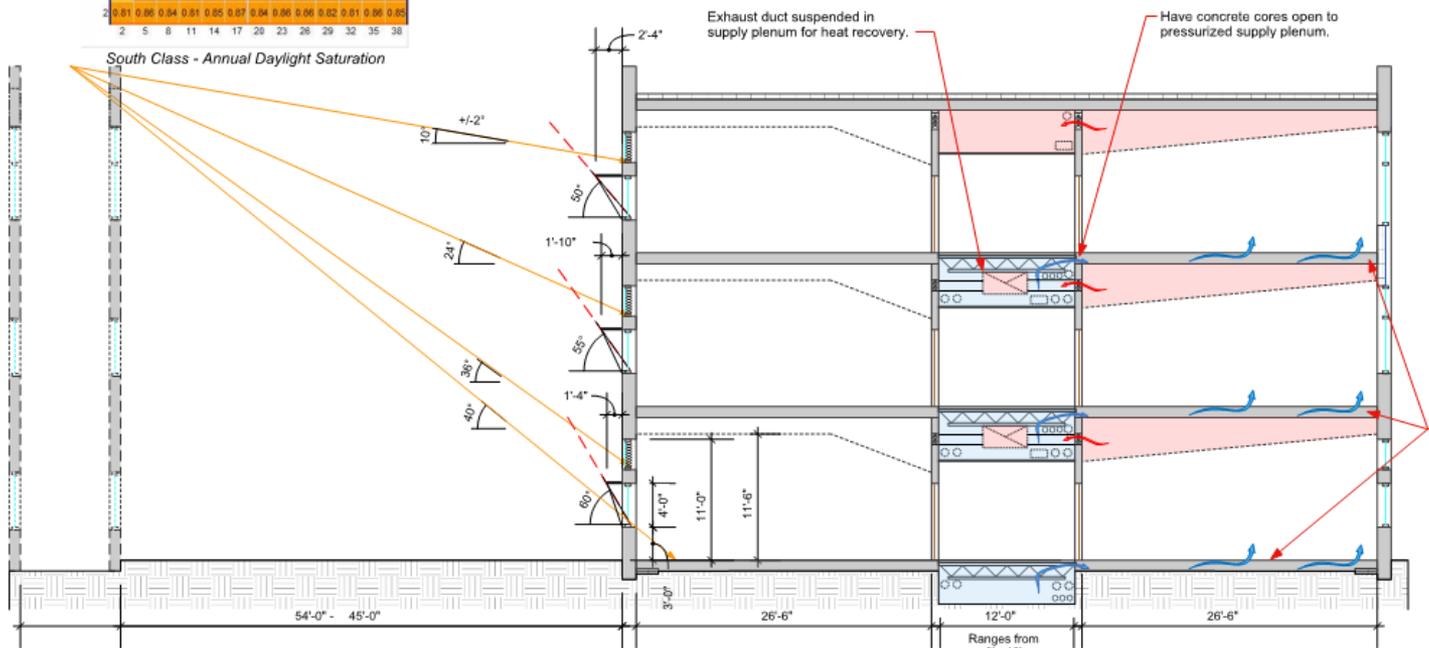
North Façade - 42%+WWRint, 16%+ WFR, ??%WWRext



North Class - Sunny Equinox, 12pm

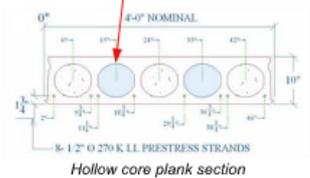
23	0.52	0.53	0.55	0.55	0.55	0.55	0.56	0.55	0.55	0.55	0.54		
20	0.54	0.55	0.56	0.56	0.57	0.57	0.57	0.58	0.58	0.57	0.56	0.56	
17	0.55	0.57	0.58	0.59	0.59	0.59	0.59	0.60	0.59	0.59	0.59	0.58	
14	0.58	0.59	0.61	0.61	0.62	0.62	0.63	0.63	0.62	0.62	0.61	0.60	
11	0.62	0.65	0.66	0.67	0.68	0.68	0.68	0.67	0.68	0.67	0.66	0.65	
8	0.69	0.71	0.73	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.73	0.71	
5	0.70	0.74	0.75	0.75	0.76	0.75	0.76	0.76	0.76	0.76	0.75	0.74	
2	0.73	0.86	0.73	0.63	0.76	0.82	0.75	0.80	0.81	0.70	0.66	0.80	0.85
	2	5	8	11	14	17	20	23	26	29	32	35	38

North Class - Annual Daylight Saturation



Alternative 2 Classroom Wing Section

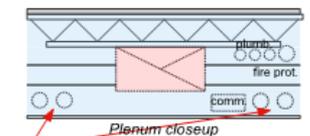
Supply air channels alternating with concrete cores



Hollow core plank section



Hollow core floor option

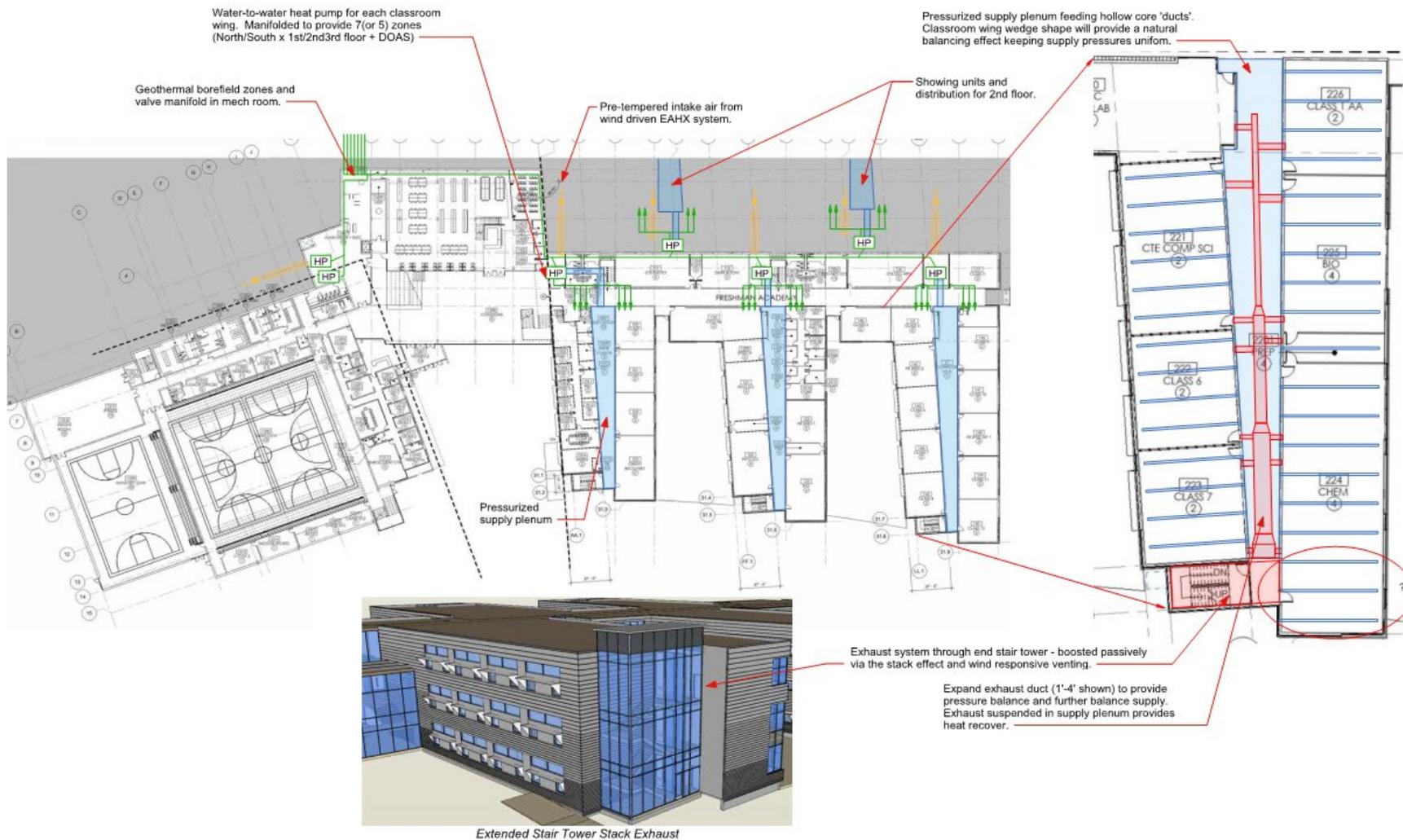


Plenum closure

Radiant floor loops



Hillwood HS – passive thermal strategies





Robeson County MS Prototype



Media Center Section View - Base Case, Sunny Equinox, 12:00PM



Media Center View from West - Base Case, Sunny Equinox, 12:00PM



Media Center Section View - Alternative 2, Sunny Equinox, 12:00PM



Media Center View from West - Alternative 2, Sunny Equinox, 12:00PM



Robeson County MS Prototype



Base Case - View from Northwest Corner, Sunny Equinox, 12pm



Alternative 1 - View from Northwest Corner, Sunny Equinox, 12pm



Base Case - View from Southeast Corner, Sunny Equinox, 12pm



Alternative 1 - View from Southeast Corner, Sunny Equinox, 12pm



Base Case - Sectional Rendering, Sunny Equinox, 12pm

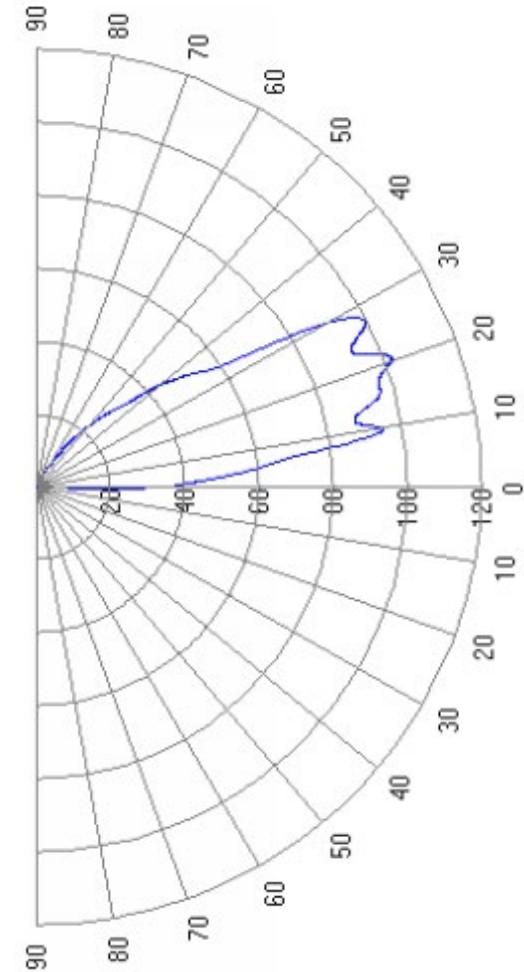
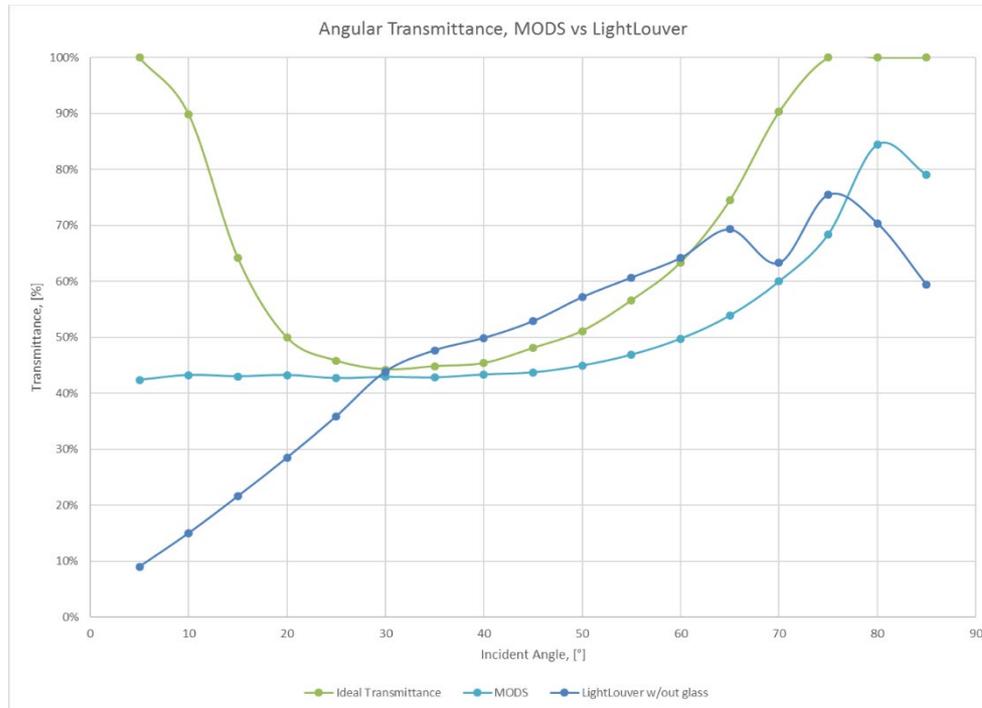


Alternative 1 - Sectional Rendering, Sunny Equinox, 12pm



LightLouver MODS

- Next generation LightLouver is in the works!
 - Patents approved
 - Prototype underway
 - BSDF files available soon – contact me if interested!





Questions?

Experiences with Radiance in Daylighting Design, Part VIII

**18th International Radiance Conference
August 21-22, New York City**

**Zack Rogers, P.E., IESNA, LEED AP BD+C
Daylighting Innovations, LLC**



**DAYLIGHTING
INNOVATIONS**