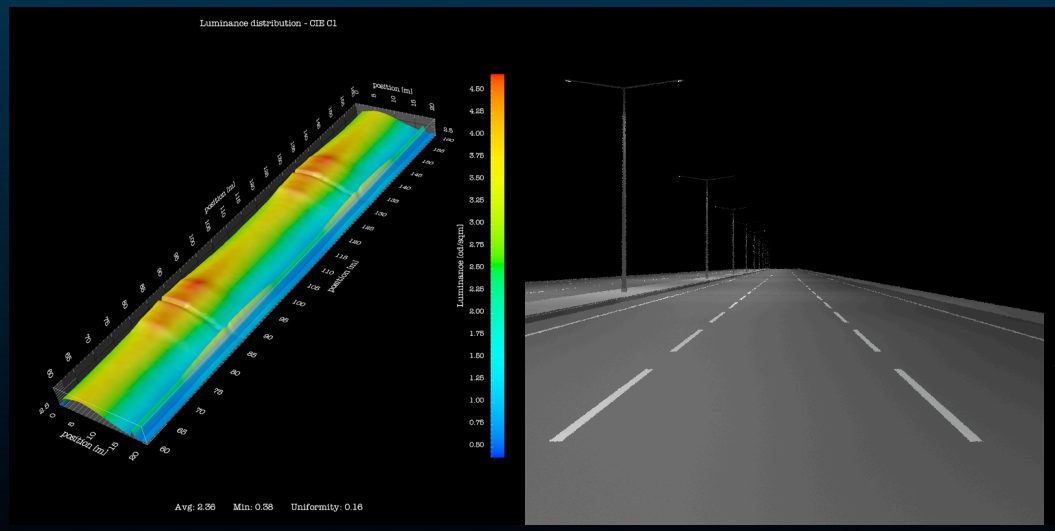
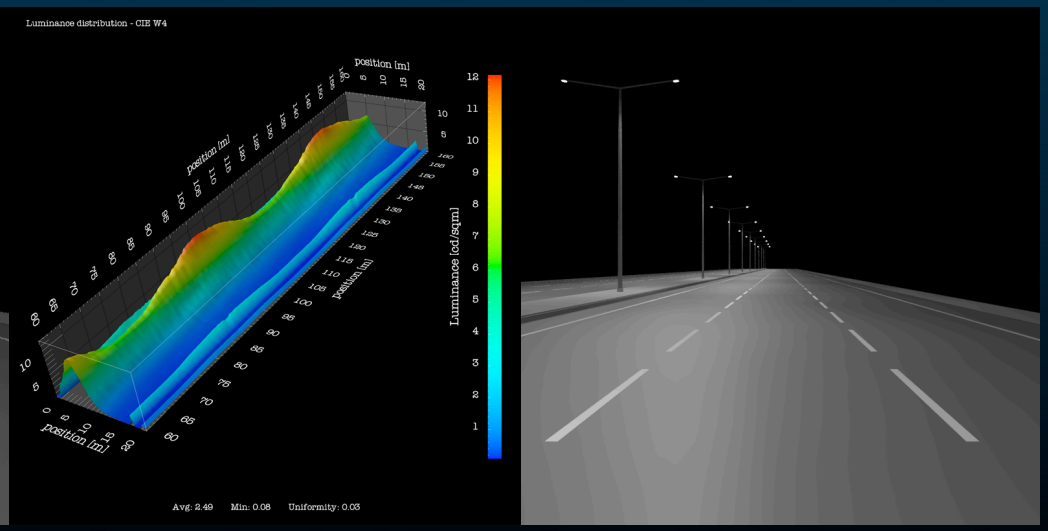
3rd International Radiance Workshop - Fribourg 2004

Road lighting simulation in Radiance

(with accurate road surface modelling)





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Summary

Part I - *Introduction*

Part II - *r-Table implementation*

Part III - *Examples and applications*

Part IV - Future work

Part I

Introduction

Introduction or “why road surface modelling?”

- Current standards require to perform luminance calculation of road surface.
- Road surface is typically non lambertian. Its properties are described by CIE and often presented in standards by means of tables.
- It is possible to implement in Radiance these information.
- Radiance is more customisable than any other light simulation program.

Part II

r-Table implementation

r-Table example

alfa=1°

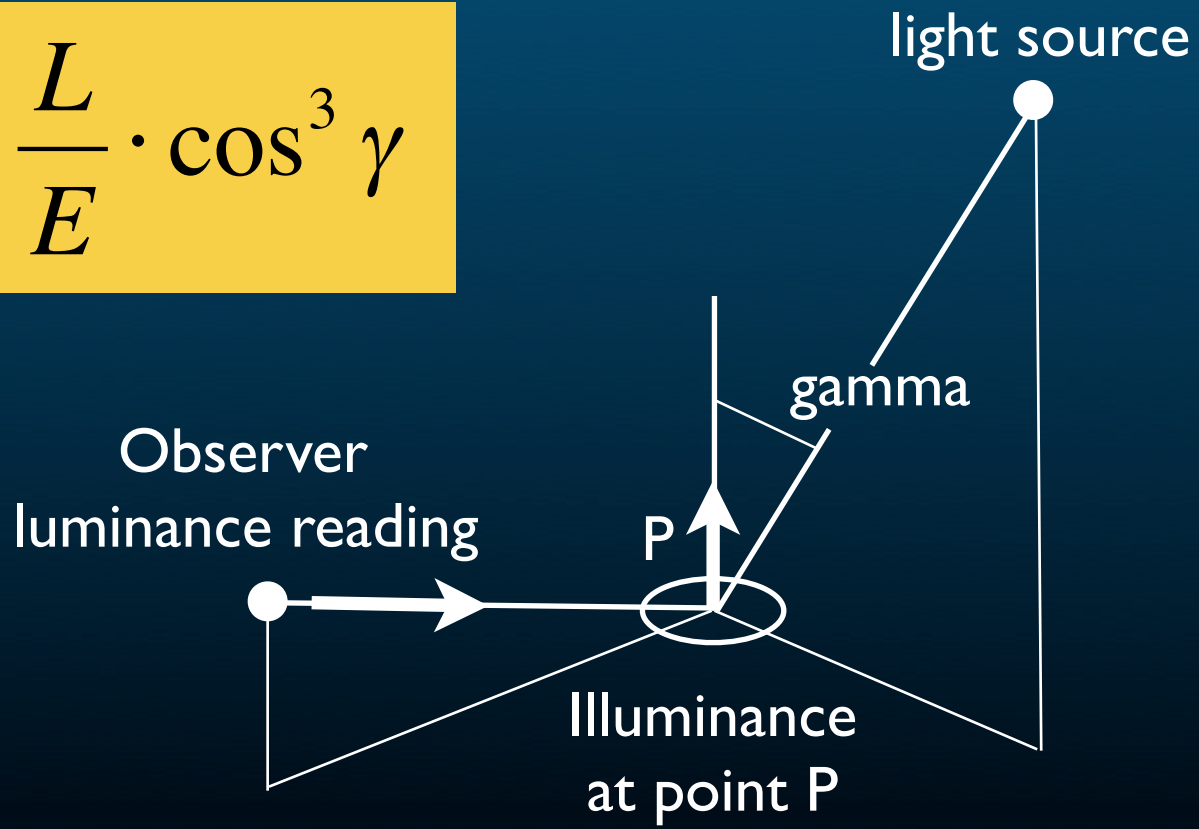
beta \ gamma	0	2	5	10	15	20	25	30	35	40	45	60	75	90	105	120	135	150	165	180
0.00	329	329	329	329	329	329	329	329	329	329	329	329	329	329	329	329	329	329	329	329
14.04	362	358	371	364	371	369	362	357	351	349	348	340	328	312	299	294	298	288	292	281
26.57	379	368	375	373	367	359	350	340	328	317	306	280	266	249	237	237	231	231	227	235
36.87	380	375	378	365	351	334	315	295	275	256	239	218	198	178	175	176	176	169	175	176
45.00	372	375	372	354	315	277	243	221	205	192	181	152	134	130	125	124	125	129	128	128
51.34	375	373	352	318	265	221	189	166	150	136	125	107	91	93	91	91	88	94	97	97
56.31	354	352	336	271	213	170	140	121	109	97	87	76	67	65	66	66	67	68	71	71
60.26	333	327	302	222	166	129	104	90	75	68	63	53	51	49	49	47	52	51	53	54
63.43	318	310	266	180	121	90	75	62	54	50	48	40	40	38	38	38	41	41	43	45
68.20	268	262	205	119	72	50	41	36	33	29	26	25	23	24	25	24	26	27	29	28
71.57	227	217	147	74	42	29	25	23	21	19	18	16	16	17	18	17	19	21	21	23
74.05	194	168	106	47	30	22	17	14	13	12	12	11	10	11	12	13	15	14	15	14
75.96	168	136	76	34	19	14	13	11	10	10	10	8	8	9	10	9	11	12	11	13
77.47	141	111	54	21	14	11	9	8	8	8	8	7	7	8	8	8	8	10	10	11
78.69	126	90	43	17	10	8	8	7	6	6	7	6	7	6	6	7	8	8	8	9
79.70	107	79	32	12	8	7	7	7	6	5	0	0	0	0	0	0	0	0	0	0
80.54	94	65	26	10	7	6	6	6	5	0	0	0	0	0	0	0	0	0	0	0
81.25	86	56	21	8	7	6	5	5	0	0	0	0	0	0	0	0	0	0	0	0
81.87	78	50	17	7	5	5	5	5	0	0	0	0	0	0	0	0	0	0	0	0
82.41	70	41	14	7	4	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0
82.87	63	37	11	5	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0
83.29	60	37	10	5	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0
83.66	56	32	9	5	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83.99	53	28	9	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
84.29	52	27	7	5	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
84.56	45	23	7	4	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
84.81	43	22	7	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85.03	44	22	7	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85.24	42	20	7	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

r-Table for concrete road surface, Class C2

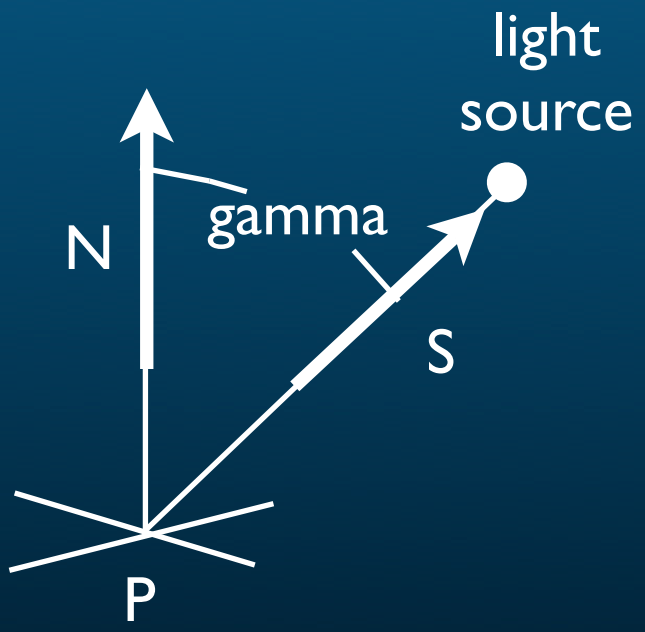
Road surface properties and r-Table

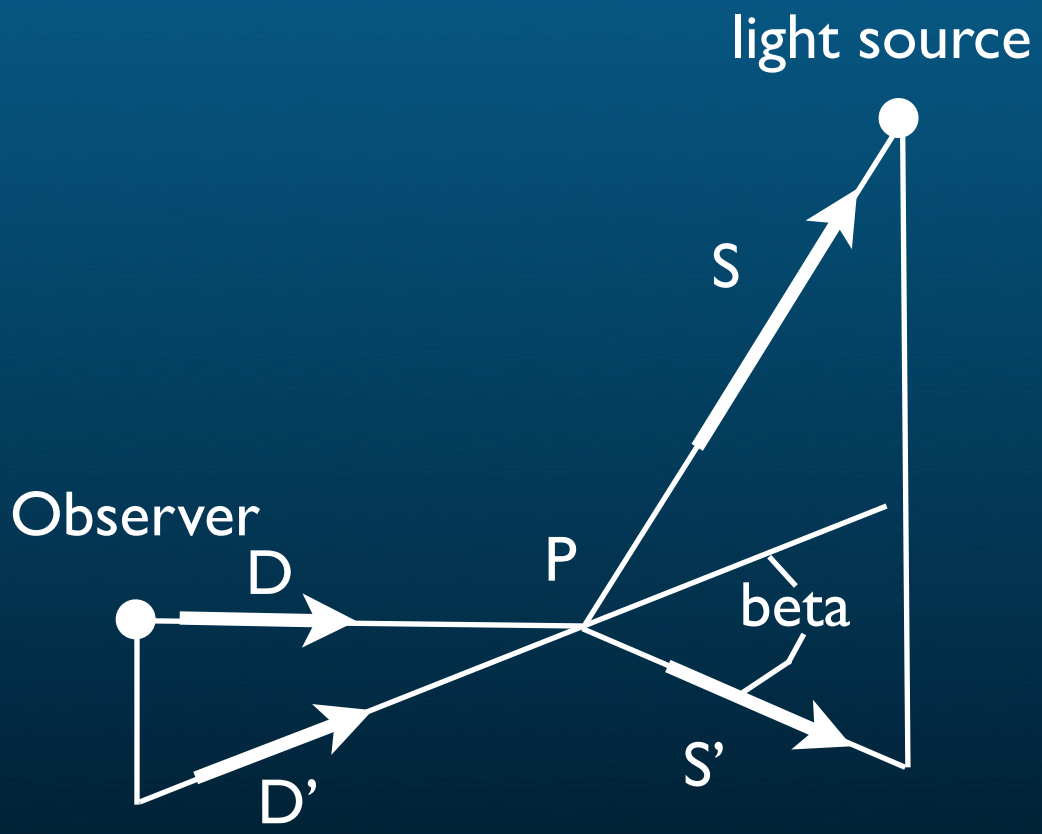
"r-Tables" collect *reduced luminance coefficients*, defined as:

$$[1]\quad r = \frac{L}{E} \cdot \cos^3 \gamma$$



r-Table variables

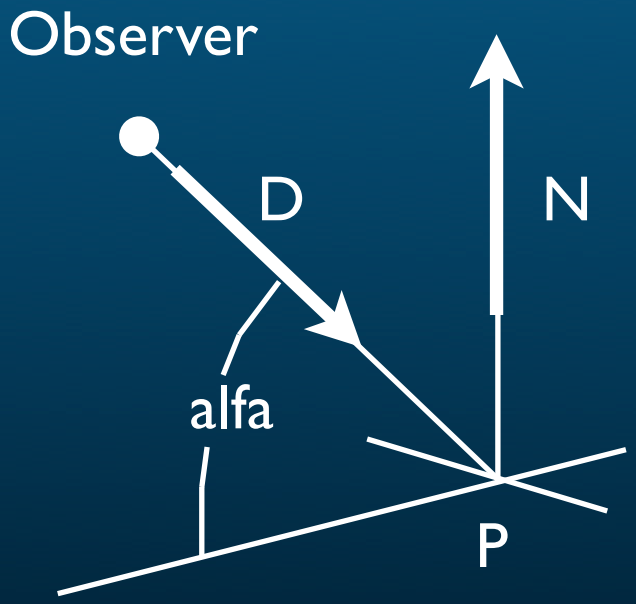




[2] $\gamma = \arccos(\vec{N} \cdot \vec{S})$

[3] $\beta = \arccos(\vec{D}' \cdot \vec{S}')$

r - Table variables



[4] $\alpha = \arcsin(-\vec{D} \cdot \vec{N})$

r-Tables consider only one observer position: $\alpha = 1^o$

r-Table

[2] $\gamma = \arccos(\vec{N} \cdot \vec{S})$

[3] $\beta = \arccos(\vec{D}' \cdot \vec{S}')$

gamma

beta

	0	2	5	10	15	20	25	30	35	40	45	60	75	90	105	120	135	150	165	180
0.00	329	329	329	329	329	329	329	329	329	329	329	329	329	329	329	329	329	329	329	329
14.04	362	358	371	364	371	369	362	357	351	349	348	340	328	312	299	294	298	288	292	281
26.57	379	368	375	373	367	359	350	340	328	317	306	280	266	249	237	237	231	231	227	235
36.87	380	375	378	365	351	334	315	295	275	256	239	218	198	178	175	176	176	169	175	176
45.00	372	375	372	354	315	277	243	221	205	192	181	152	134	130	125	124	125	129	128	128
51.34	375	373	352	318	265	221	189	166	150	136	125	107	91	93	91	91	88	94	97	97
56.31	354	352	336	271	213	170	140	121	109	97	87	76	67	65	66	66	67	68	71	71
60.26	333	327	302	222	166	129	104	90	75	68	63	53	51	49	49	47	52	51	53	54
63.43	318	310	266	180	121	90	75	62	54	50	48	40	40	38	38	38	41	41	43	45
68.20	268	262	205	119	72	50	41	36	33	29	26	25	23	24	25	24	26	27	29	28
71.57	227	217	147	74	42	29	25	23	21	19	18	16	16	17	18	17	19	21	21	23
74.05	194	168	106	47	30	22	17	14	13	12	12	11	10	11	12	13	15	14	15	14
75.96	168	136	76	34	19	14	13	11	10	10	10	8	8	9	10	9	11	12	11	13
77.47	141	111	54	21	14	11	9	8	8	8	8	7	7	8	8	8	8	10	10	11
78.69	126	90	43	17	10	8	8	7	6	6	7	6	7	6	6	7	8	8	8	9
79.70	107	79	32	12	8	7	7	7	6	5	0	0	0	0	0	0	0	0	0	0
80.54	94	65	26	10	7	6	6	6	5	0	0	0	0	0	0	0	0	0	0	0
81.25	86	56	21	8	7	6	5	5	0	0	0	0	0	0	0	0	0	0	0	0
81.87	78	50	17	7	5	5	5	5	0	0	0	0	0	0	0	0	0	0	0	0
82.41	70	41	14	7	4	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0
82.87	63	37	11	5	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0
83.29	60	37	10	5	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0
83.66	56	32	9	5	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83.99	53	28	9	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
84.29	52	27	7	5	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
84.56	45	23	7	4	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
84.81	43	22	7	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85.03	44	22	7	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85.24	42	20	7	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

alfa= 1°

[5] $\frac{\rho}{\pi} = \frac{L}{E} = \frac{r}{\cos^3 \gamma \cdot 10000}$

r-Table and Radiance

r-table.cal	-	used to define angles
r-table.data	-	used to specify values of r-table and angles
model.mat	-	used to define road surface material
model.rad	-	used to create road geometry

r-Table.cal

gamma(x,y,z) = Acos (x*Nx + y*Ny + z*Nz);

beta(x,y,z) = if(sqrt(x^2 + y^2), Acos ((x/sqrt(x^2 + y^2)) * (Dx/sqrt(Dx^2 + Dy^2)) +
+(y/sqrt(x^2 + y^2)) * (Dy/sqrt(Dx^2 + Dy^2))), 0);

alfa(x,y,z) = Asin (-Dx*Nx - Dy*Ny - Dz*Nz);

refl(v,x,y,z) = v / (10000 * (x*Nx + y*Ny + z*Nz)^3);

[2] $\gamma = \arccos(\vec{N} \cdot \vec{S})$

[3] $\beta = \arccos(\vec{D}' \cdot \vec{S}')$

[4] $\alpha = \arcsin(-\vec{D} \cdot \vec{N})$

[5] $\frac{\rho}{\pi} = \frac{L}{E} = \frac{r}{\cos^3 \gamma \cdot 10000}$

r-Table.data

3	number of variables
0 0 n	first variable (alfa)
.....	n values
0 0 29	second variable (beta)
.....	29 values
0 0 20	third variable (gamma)
.....	20 values
770 770...	data
.....	.....
....	

....

....

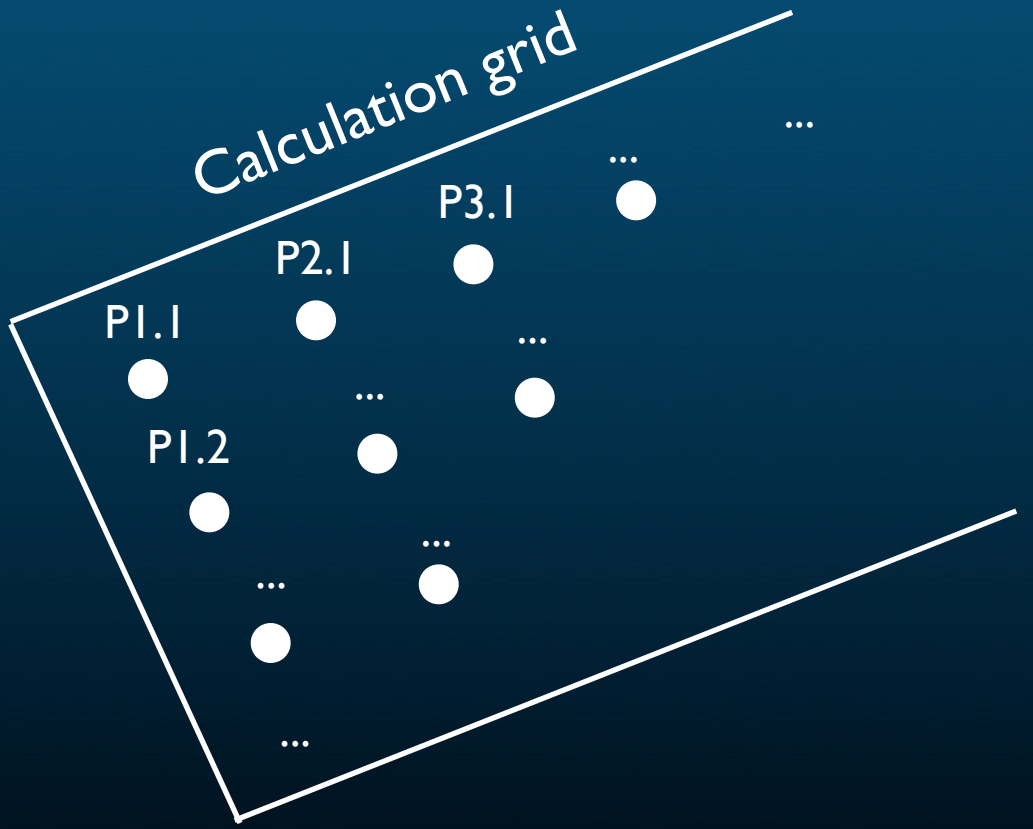
r-Table.mat

```
void plasdata road
6 refl r-table.data r-table.cal alfa gamma beta
0
4 r g b 1
```

Part III

Examples and applications

Road surface illuminance calculation



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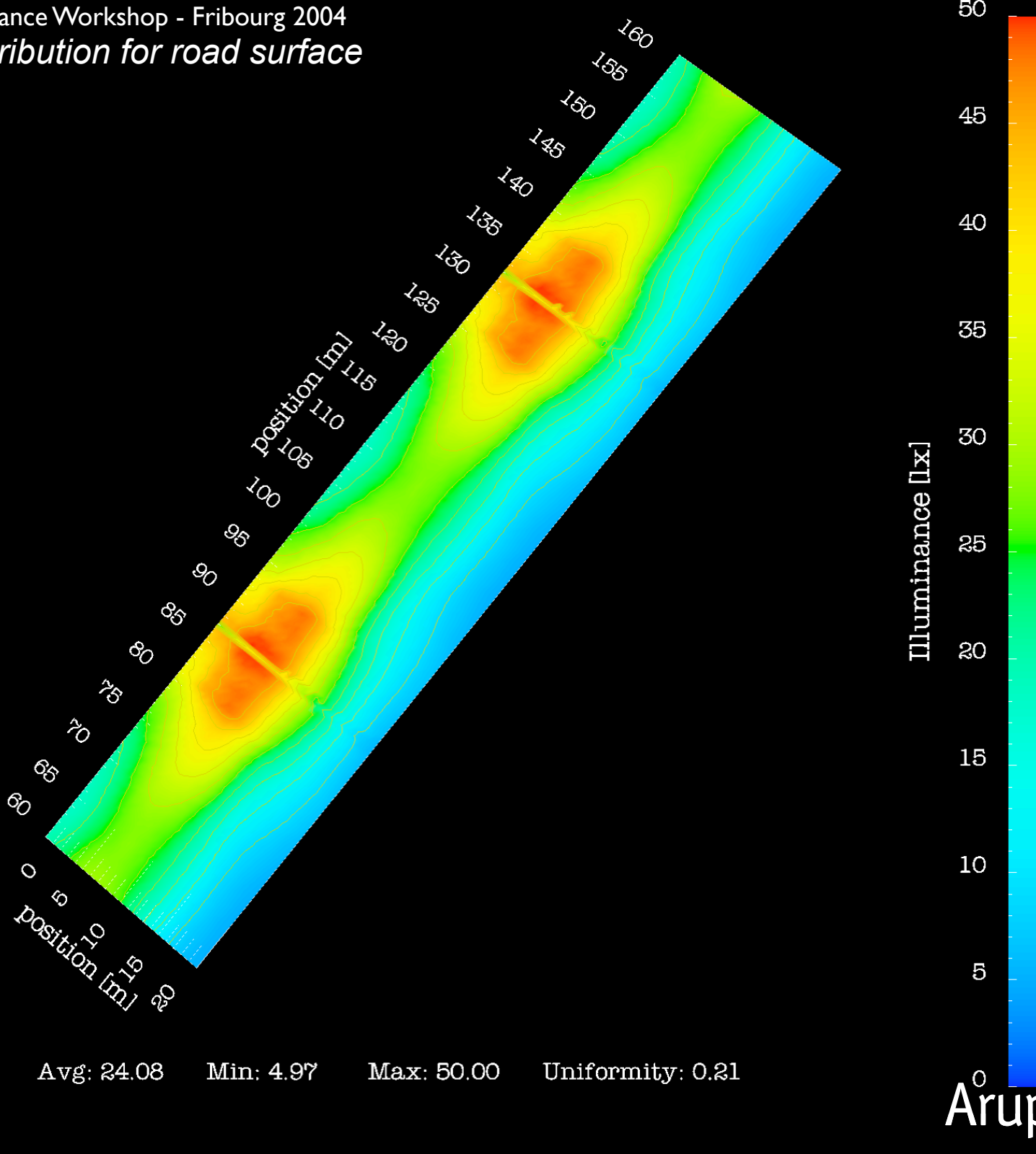
Illuminance distribution for road surface



Avg: 24.08 Min: 4.97 Max: 50.00 Uniformity: 0.21

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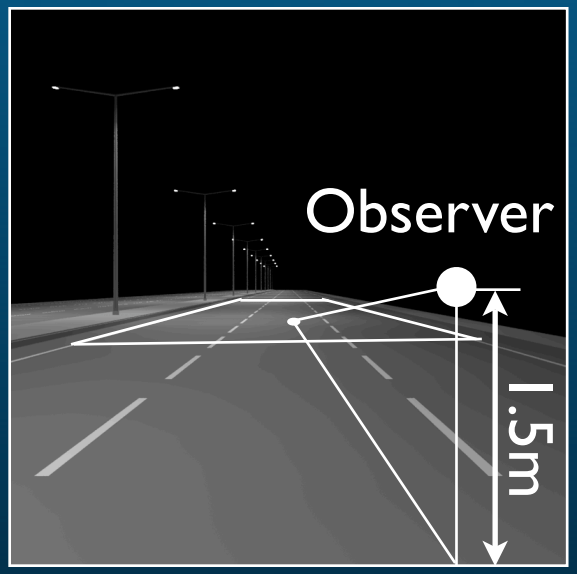
Road surface luminance calculation



Calculation grid

P3.1 ...

P2.1 ...

P1.1 ... ...

P1.2 ... ...

luminance reading

Observer

1.5m

60m

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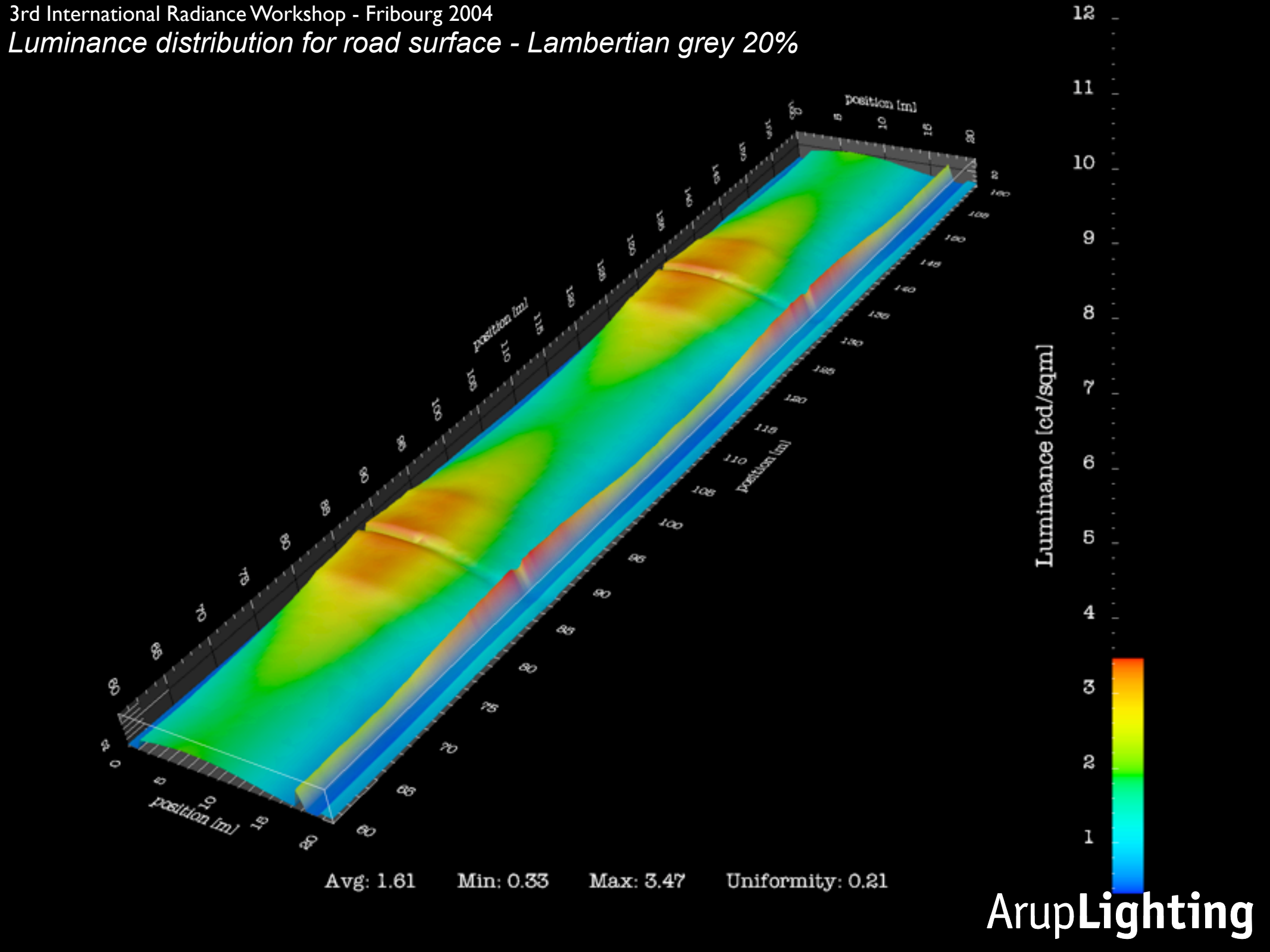
Luminance distribution for road surface - Lambertian grey 20%



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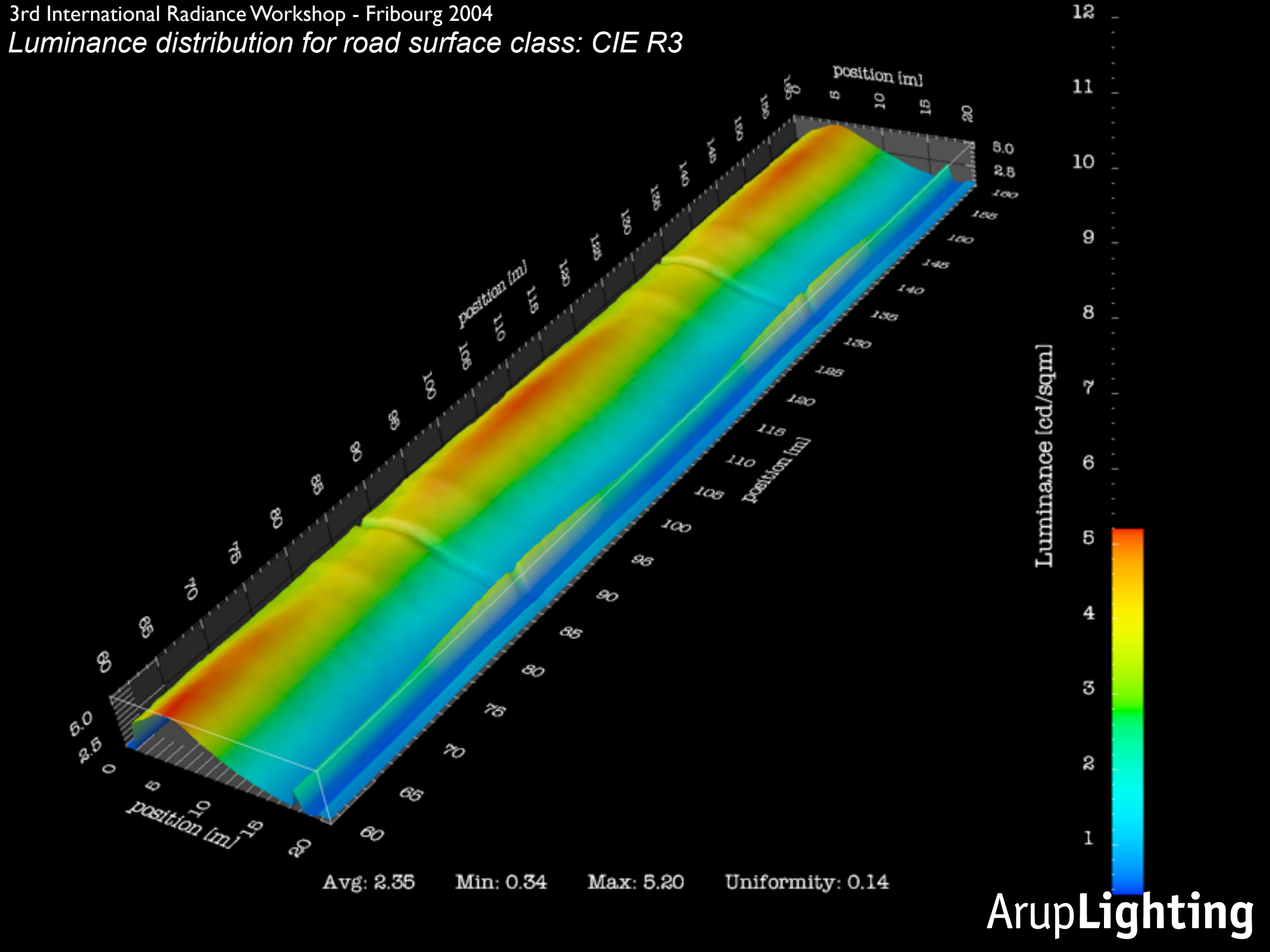
Luminance distribution for road surface class: CIE R3



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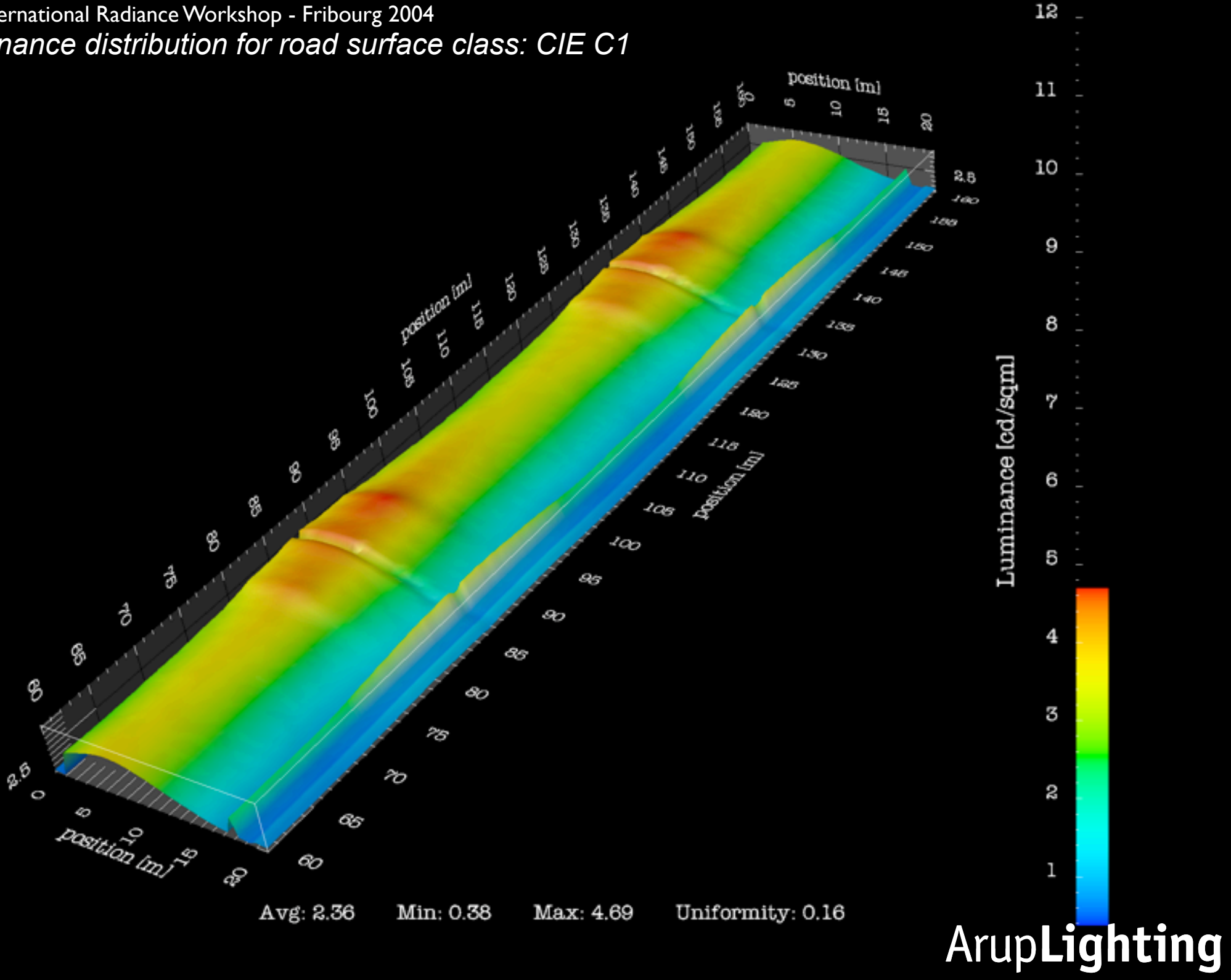
Luminance distribution for road surface class: CIE C1



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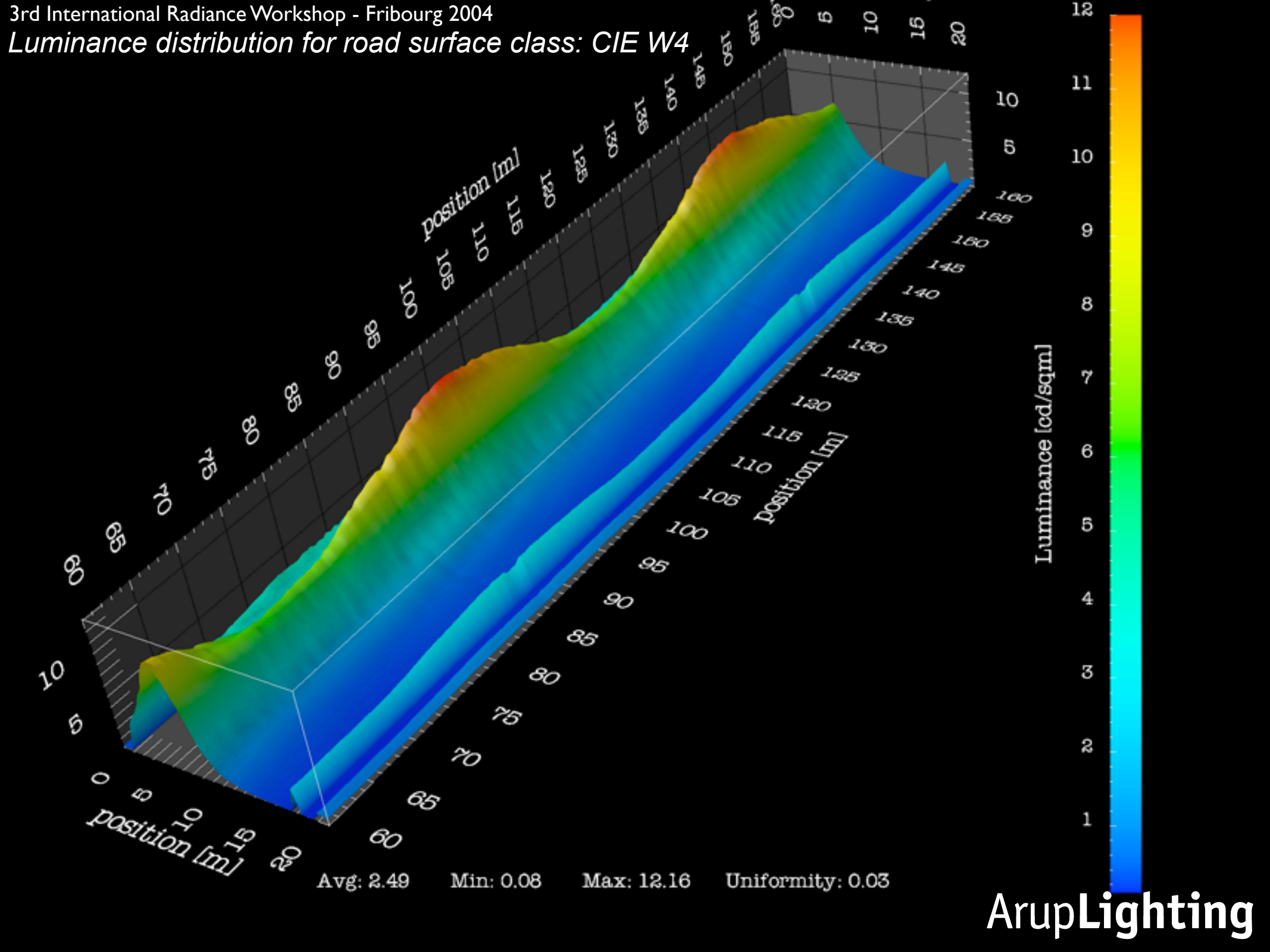
Luminance distribution for road surface class: CIE W4



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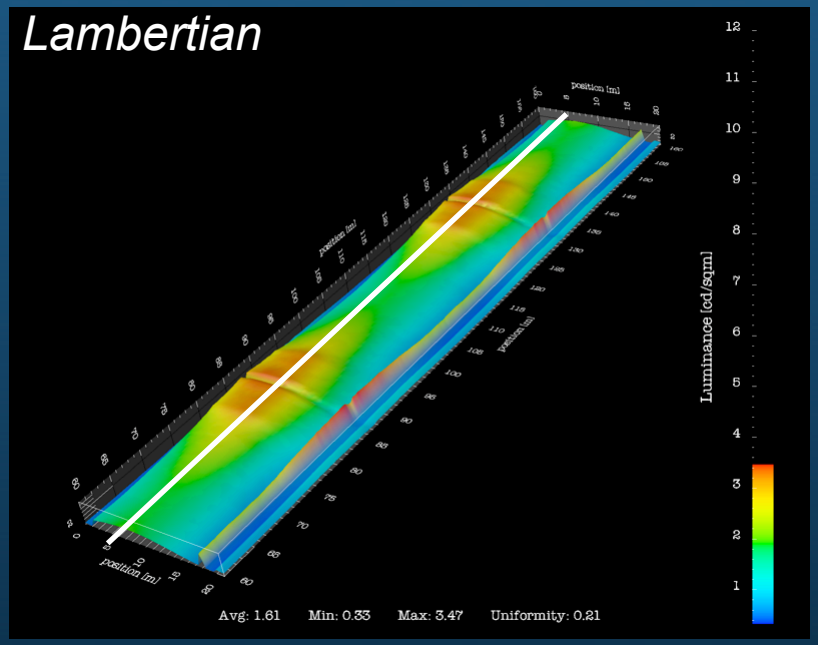
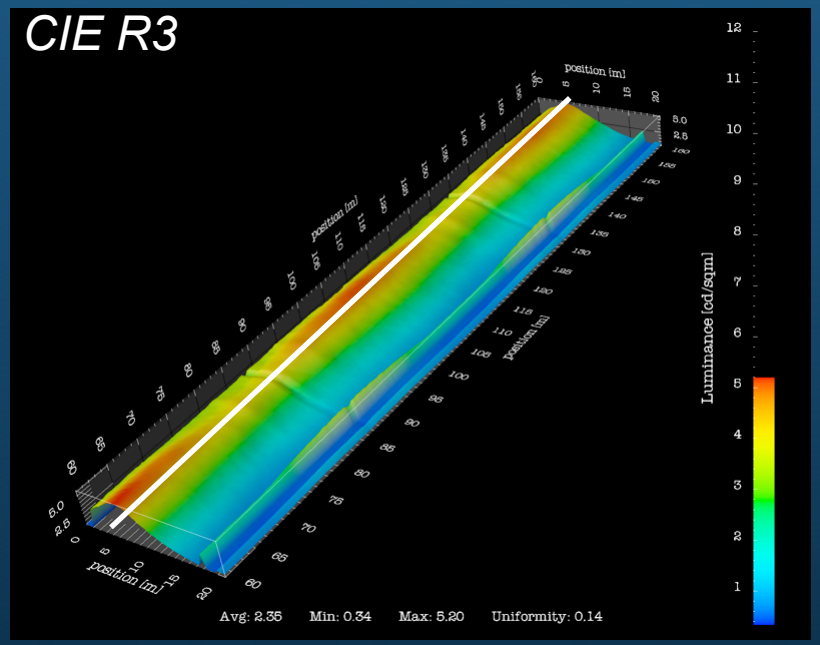
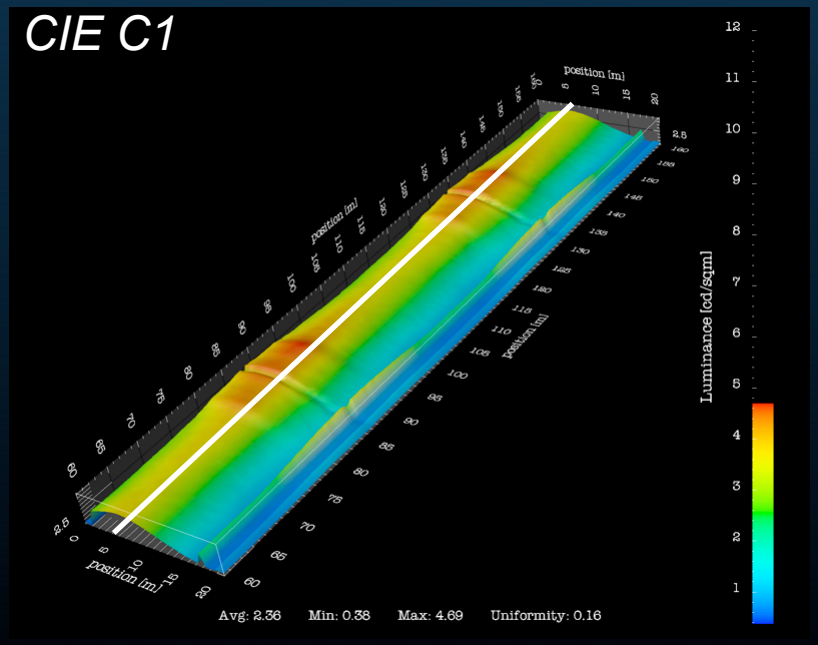


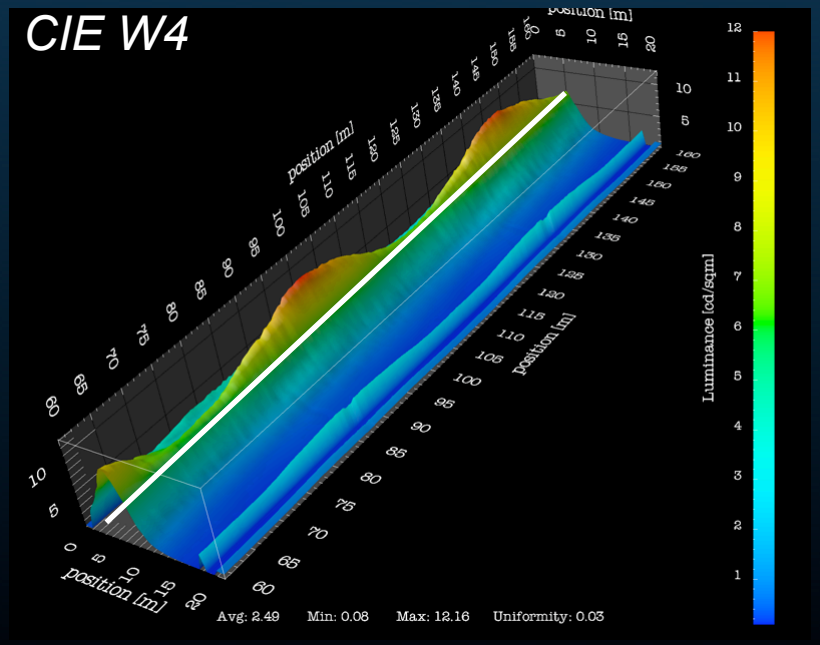
Longitudinal Uniformity: U_L=0.46



Longitudinal Uniformity: U_L=0.71



Longitudinal Uniformity: U_L=0.69



Longitudinal Uniformity: U_L=0.43

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Lambertian

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CIE W4

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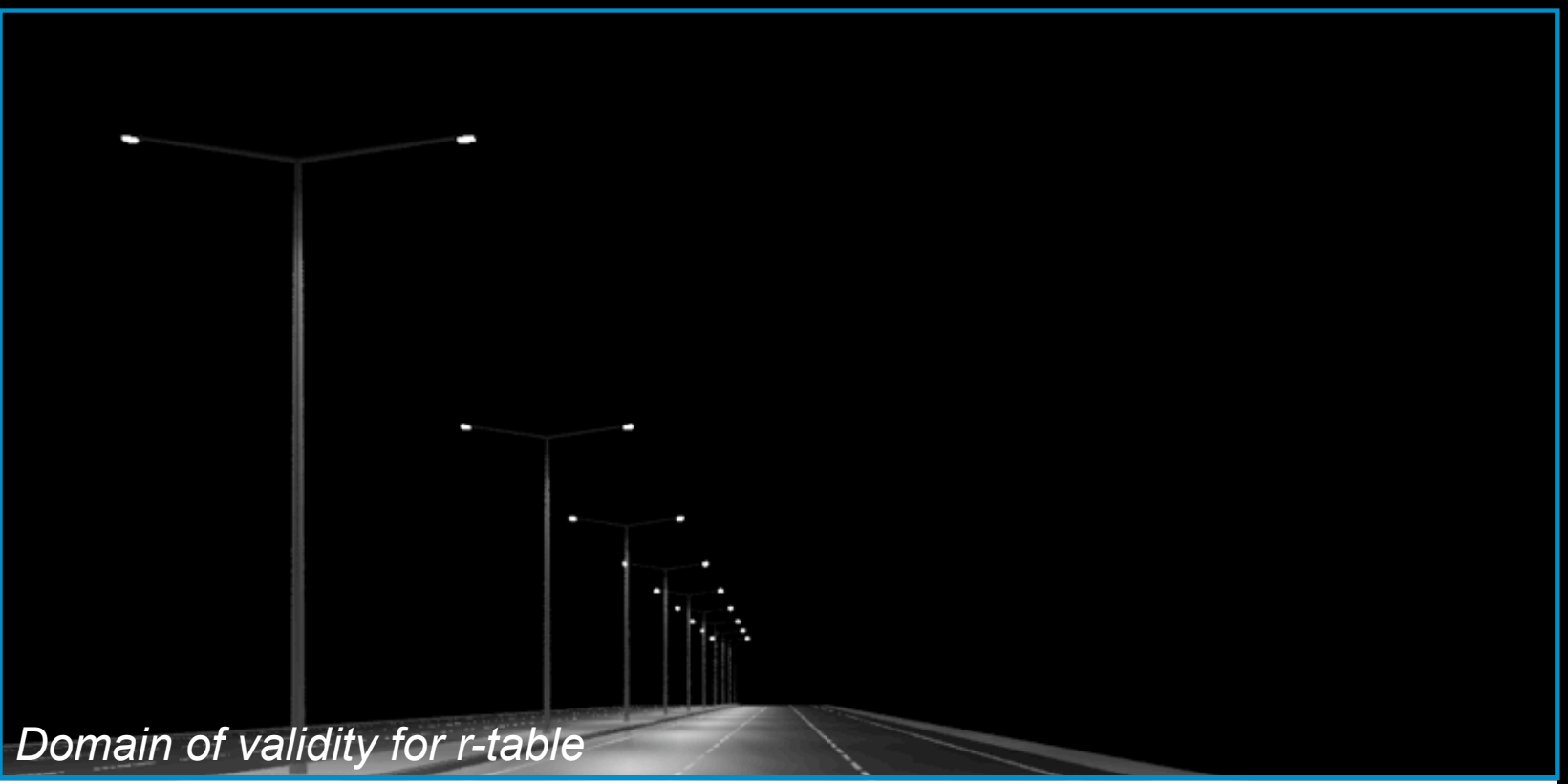

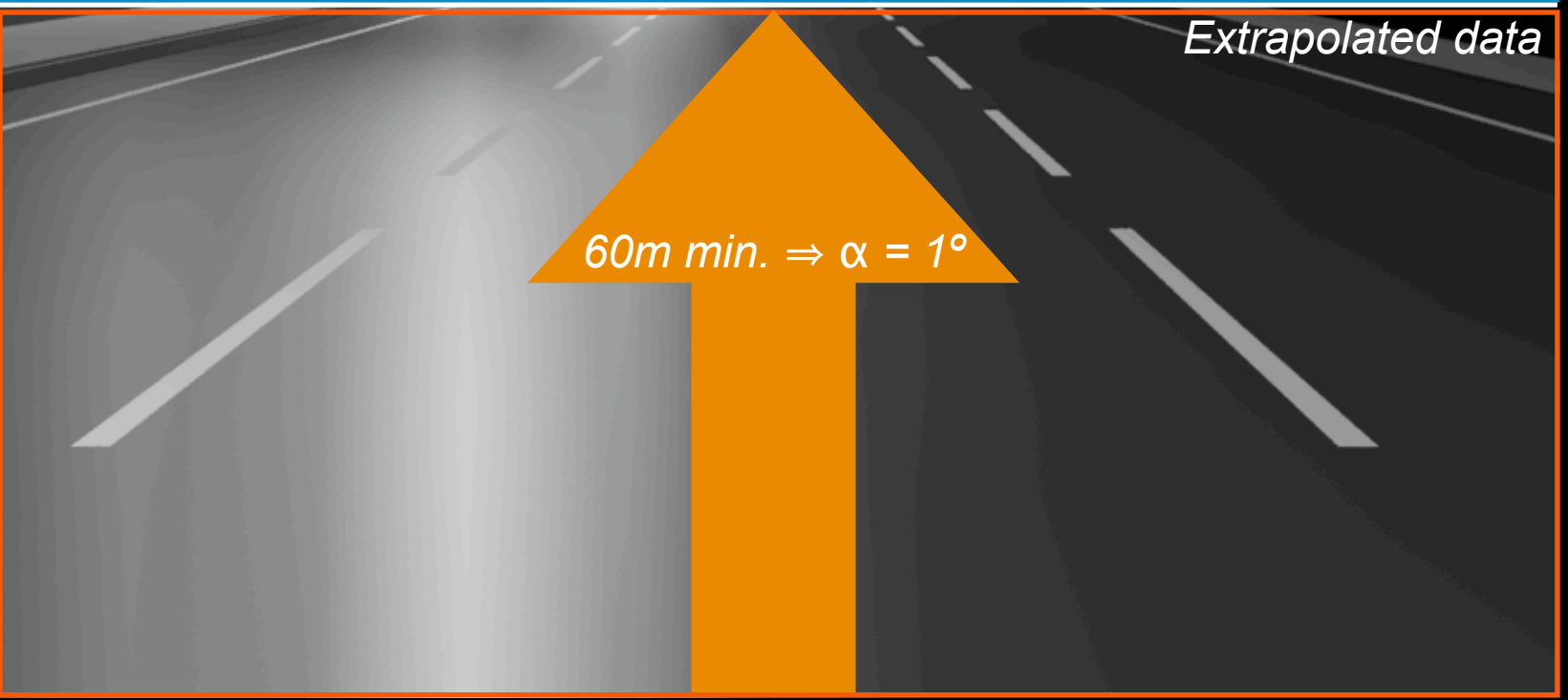

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Part IV

Future work

Work in progress:

- Create a shell program for generating simple road light schemes and verifying compliance to standards.

- Implement an inexpensive HDR based technique to expand r-tables in order to describe more than a single observer position.

Thanks!

References:

- Rendering with Radiance, Chapter 7 - “Roadway lighting” by Erich Phillips.
- BS 5489-1:2003 “Code of practice for the design of road lighting”.
- BS EN 13201-2:2003 “Road lighting - Part 2: Performance requirements”.
- BS EN 13201-3:2003 “Road lighting - Part 3: Calculation of performance”.