Roadpollution: a software to evaluate and understand light pollution from road lighting

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Aims

- Main aim : To obtain the upward light distribution of large areas to compare with satellite measurements
- By-product: to evaluate and compare the polluting power of lighting installations

Work in progress...

Do not expect that it be completed in few months: it is a low priority project …sorry

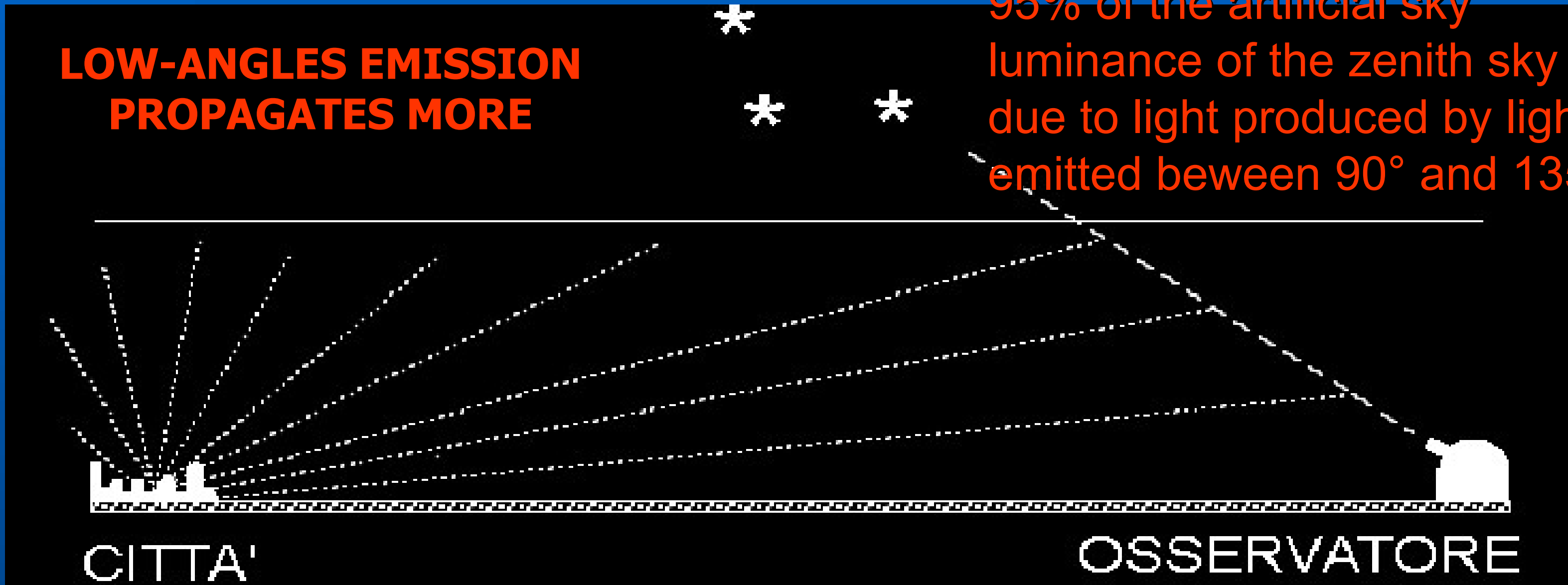
Methods

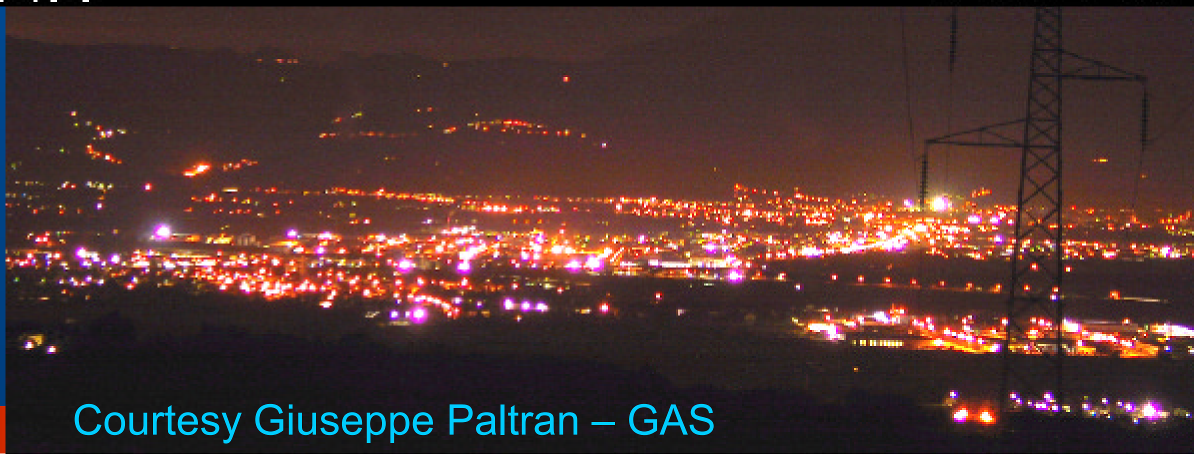
INPUT
- Road parameters & luminaire photometry
- Road design computation (UNI10439)

OUTPUT
- Road lighting data
- Parameters related to energy saving
- Integrated upward light parameters
- Parameters dependent on the direction of emission of the light
- Parameters related to scattering (along light paths via Garstang models)
- Reflected light by road (Gillet et al. 2002) and surfaces outside of the road (estimate)

Effects of the emission angle

AT 20 km from the source
95% of the artificial sky luminance of the zenith sky is due to light produced by light emitted beween 90° and 135°

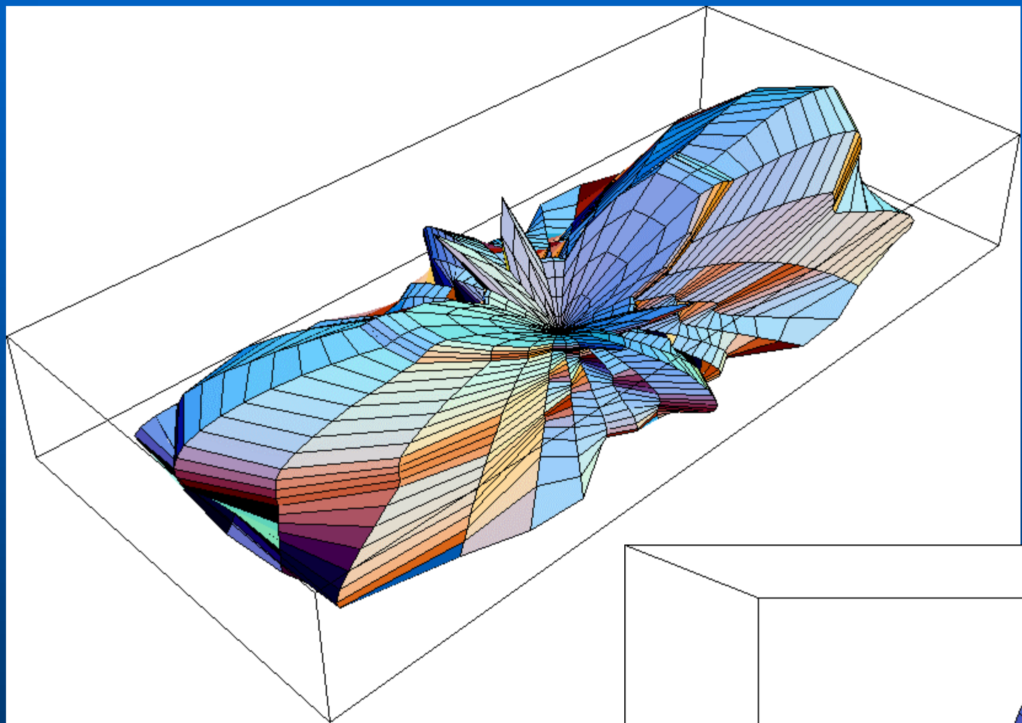




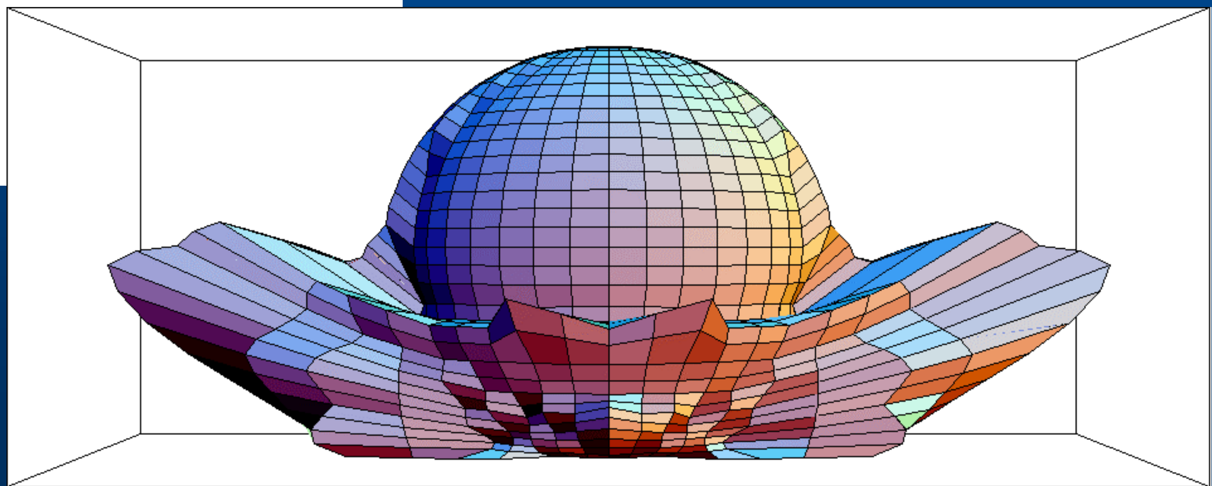
Output data

Let's quickly look at one of the output files

Upward light distribution



For more accurate result the luminance coefficients of CIE C2 road surfaces are needed as function of q(b,g,a) for a ¹ 0



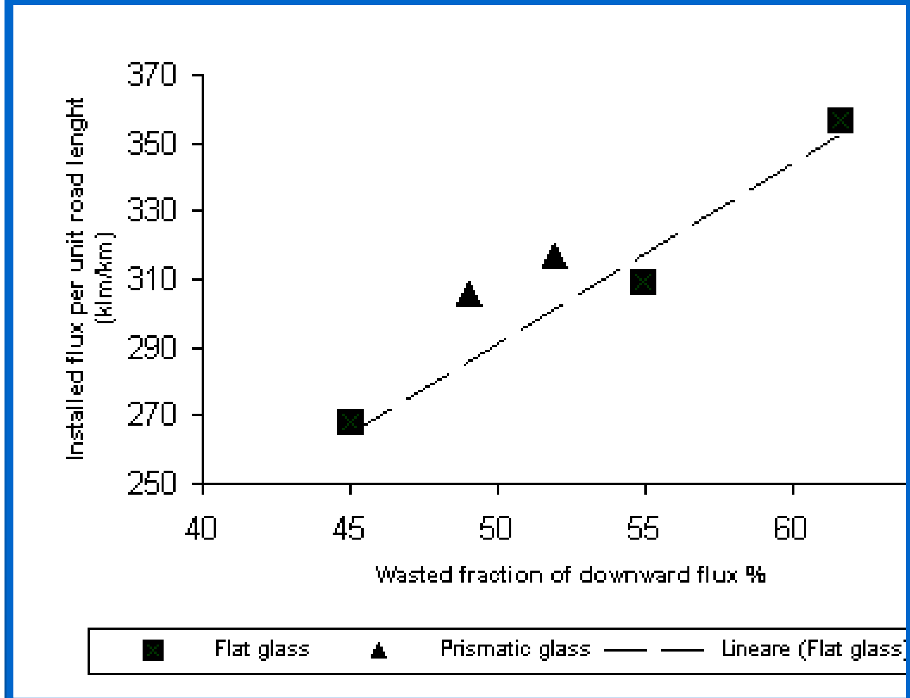
An application

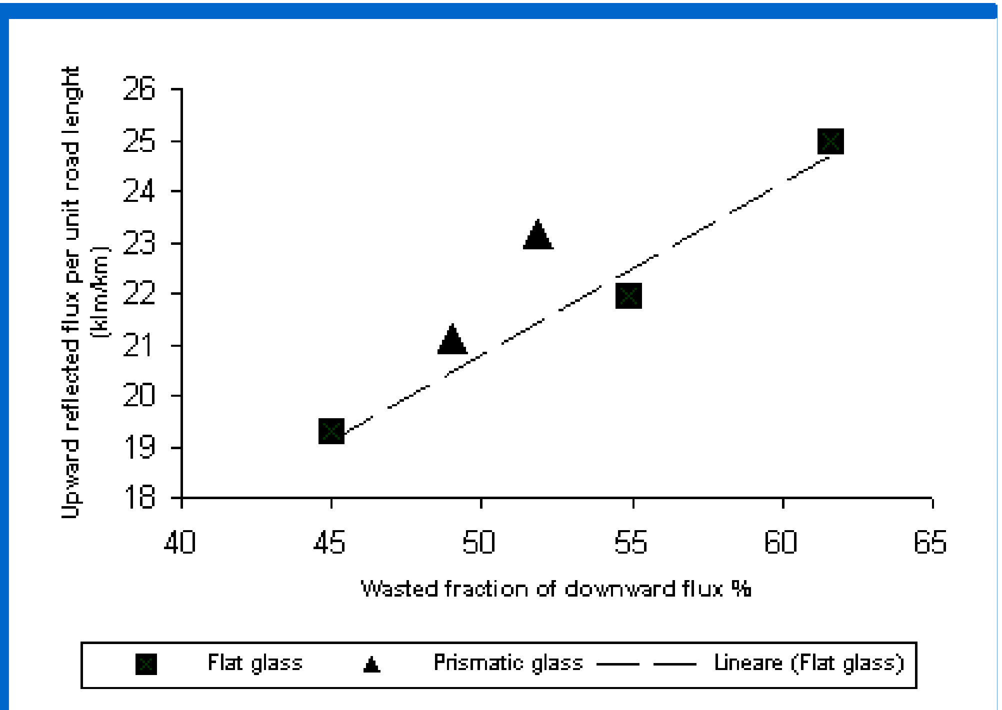
- 5 road installations: ULOR_inst = 2.2%,0.2%,»0%
- searching at our best for the minimum installed flux per unit length and the maximum pole spacing
  - Average maintained luminance »1cd/klm
  - Overall uniformity U_0 ³ 0.4
  - Lengthwise uniformity U_l ³ 0.5
  - Threshold index TI£ 15%
  - Lumen depreciation factor 0.8
  - C2 standard road surface
  - Road width 7 m
  - Overhang free
  - No tilt

DESIGN PARAMETERS					
code number	09170114	09170102	09170043	09162356	09170209
luminaire kind	prismatic glass	convex transparent glass	flat glass	flat glass	flat glass
lamp flux (klm)	11	13	15	10.8	7.5
pole spacing (m)	36	41	42	35	28
luminaire height (m)	8	8	12	10	8
lamp	HQL	SON-T	NAV-T	NAV-T	NAV-T
ROAD PARAMETERS (luminaires at right/luminaires at left)					
average maintained luminance	1.0/1.0	1.0/1.0	1.0/1.0	1.0/1.0	1.0/1.0
overall uniformity U_0	0.4/0.5	0.4/0.4	0.5/0.4	0.5/0.4	0.5/0.4
lengthwise uniformity U_L	0.5/0.5	0.5/0.5	0.5/0.6	0.5/0.6	0.5/0.7
max threshold increment TI%	10.4/11.0	13.6/9.6	6.3/9.0	6.8/9.9	6.8/9.9
ENERGY SAVING PARAMETERS					
average luminance coefficient (luminance per unit illuminance) (10^-2 cd/klm)	89	68.2	93	91	87
used fraction of the lamp flux %	35.4	40.7	28.6	33.5	40.9
wasted fraction of the downward flux %	51.0	51.9	61.6	54.9	45.0
light output ratio of the luminaire LORL %	71	84.9	74	74	74
luminaires per km	27.7	24.4	23.8	28.6	35.7
installed lamp flux per unit length (lm/m)	306	317	357	309	268
installed lamp flux per unit area (lm/m^2)	44	45	51	44	38

Some comments …by the way

- For the same pole height, the installation with flat glass fixtures results the less consuming (only 268 lm/m) due to his minor wasting of light out of the road. This likely depends on the more concentrated emission of these specific fixtures on the plane perpendicular to the road axis. The installed flux per unit road length seems depending mainly on the fraction of light wasted out of the road (I.e. on the good design) rather than on the throw.
- However the number of luminaires per unit road length is the larger one. Number of luminaires and installed flux per unit road length seems to be conflicting. E.g. using 1/3 less luminaires we would spend 1/3 more light flux. However saved energy pay the installation cost.
- The number of luminaires per km of the flat glass installation is only 3% larger than that of the prismatic glass installation, when comparing installations with the same installed flux per km and same luminance
- An accurate design seems more important than the kind of glass


370
350
330
310
290
270
250
40
45
50
55
60
Installed flux per unit road lenght (klm/km)
Wasted fraction of downward flux %
Flat glass
Prismatic glass
Lineare (Flat glass)


26
25
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18
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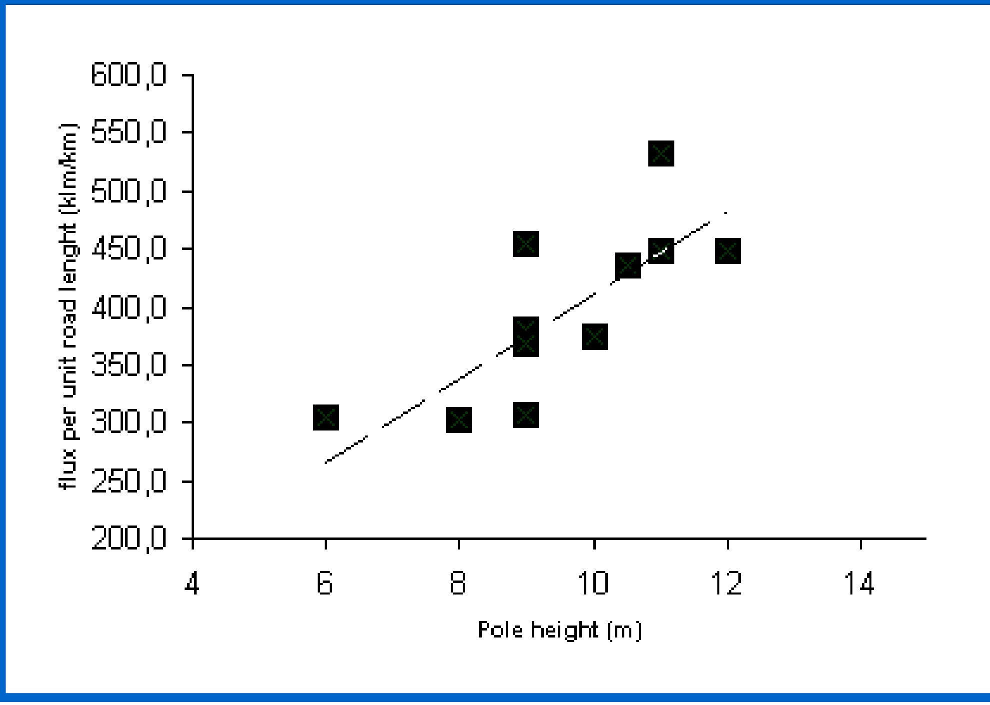
60
65
Upward reflected flux per unit road lenght (klm/km)
Wasted fraction of downward flux %
Flat glass
Prismatic glass
Lineare (Flat glass)


600,0
550,0
500,0
450,0
400,0
350,0
300,0
250,0
200,0
4
6
8
10
12
14
flux per unit road lenght (klm/km)
Pole height (m)

Preliminary results: direct light

upward light output ratio ULOR (calc) %	1.6	0.17
upward flux ratio $UFR_{luminaire}$ %	2.2	0.2
road upward flux ratio UFR_{road} %	3.7	3.8
increase of upflux ratio due to direct emission %	60	5.3
increase of scattered light due to direct emission %	85	NA
increase of low-angles upward flux due to direct emission %	167	16
increase of low-angles scattered light due to direct emission %	212	21

- Luminaires with upward flux factors apparently as small as 0.2% and 2.2% produces increases of scattered light at low elevations of the order of 20% and 200%.

Preliminary results: road reflected light

installed lamp flux per unit length (lm/m)	306	317	357	309	268
road upward flux ratio UFR_{road} %	3.7	3.8	2.9	3.4	4.2
road upward flux (lm/m)	1132	1204	1035	1050	1125

- The *road upward flux ratio* can be misleading. Installations could show an increasing road upward flux ratio but a decreasing installed lamp flux per unit road length, so the upward flux does not changes.
- Our flat glass luminaires produces slightly less road upward flux than the other two kinds (even 10-15% at the same pole height), just the opposite of what has been frequently claimed.
- Low angles road intensity depends on the required luminance

Preliminary results: out of road refl.

upward flux ratio $UFR_{luminaire}$ %	2.2	0.2	0	0	0
road upward flux (lm/m)	1132	1204	1035	1050	1125
increase of low angles scattered light due to direct + out-of-road emission % (reflectivity=13.5%)	348	170	227	172	114
increase of low angles scattered light due to direct + out-of-road emission % (reflectivity=7%)	280	95	113	86	57

- **The upward flux due to reflection by out-of-road surfaces is strictly depending on the wasted fraction of the downward flux which must be minimized as much as possible.**
- **For accurate installations, reflection of downward light wasted outside the road can add to the low angles scattered flux approximately another 60% - 110%, depending on the reflectivity**
- **The control of downward light wasted out of the road, i.e. the control of the wasted flux ratio cannot be neglected, in particular in fully shielded installations.**

Conclusion of this exercise:

- **A luminaire with ULR=0.2% still add non negligible light pollution to the road (unavoidable) one. So fully shielded luminaires are needed.**
- **When we cut the direct spill light, the light reflected by surfaces outside of the road could remain (depending on their reflectance) a non negligible source of pollution even at low angles and should be limited with an accurate design.**