

LIGHT POLLUTION IN TENERIFE

There are no borders for light. It is only limited by the Earth's curved surface and diverse terrain. Even though there are no artificial light sources in protected areas, such as El Teide National Park, and even if there is no Moon in the sky, there is no guarantee that the sky is dark. Do we really need light twenty-four hours a day, and at night, when the majority of people are asleep? Is light really a common denominator for safety, carefreeness, ideas, discovery, etc?

On 31 October 1988 legislation for protection of astronomical observatories was passed in La Palma (Roques de Los Muchachos Observatory). On 22 April 1992 legislation referring to the western part of the Tenerife was introduced; it refers to the part of the island that is seen from La Palma. The purpose of the legislation is to minimize light pollution, and in the same time to enable observations of the night sky from observatories, e.g. in Roques de Los Muchachos Observatory and in El Teide National Park.

The purposes of the individual regulations are the following:

- to reduce energy consumption; indirectly also carbon dioxide, nitrogen oxides, sulphur dioxide, and other particles in the atmosphere;
- to reduce disturbances in natural habitats due to the artificial light;
- to protect nocturnal birds;
- to protect drivers, pedestrians, and other participants in the traffic from the effects of glare;
- to reduce glare in air traffic and in traffic on water;
- to reduce the influence of the artificial light to the neighbouring islands;
- to enable numerous professional and amateur astronomical observations;
- to protect dark sky for the next generations.¹

Examples of Illumination as a Bad Practice



Figure 1: Photographs are examples of illumination as a bad practice. (Photo: Tanja Premoša)

Figure 1, example 1: There are the avenue and two-lane road connecting Calle Radio Africionados Street and Avenia de Los Menceyes Street in the town San Cristobal de La Laguna. The two-lane road is illuminated with two rows of street lamps. The inner row of lamps emits white light, and the outer lamps emit yellow light. The inner row of metal-halide lamps emits high colour temperature light in the white part of the visible spectrum. White light is more damaging for the environment, biodiversity, and people. Two rows of the lamps on each side of the road are an evidence of excessive illumination. One of the reasons for that is also the fact that the avenue connects the area Finca España and university campus Campus de Guajara. There are a lot of students during the day, but at night there is no free access to the campus. The avenue is illuminated the whole night.

Figure 1, example 2: There is a part of the northern motorway in the photograph which was taken in the viewpoint Mirador de Humboldt. Due to the high number of lamps in a small area, the northern motorway, shaped like letter S is seen from the faraway areas. Excessive illumination is not a guarantee for safety. On the contrary, it causes glare which is a disturbance for drivers. However, an important fact is that vehicles themselves illuminate the road, therefore one should consider to whom this excessive illumination is dedicated. Furthermore, a part of the light reflects off the surface of the road and travels into the sky. A part of the southern motorway is illuminated as well. Due to the proximity of the motorway to the ocean, effect of the light on the biodiversity of the ocean cannot be neglected.

Figure 1, example 3: There is a shopping centre El Corte Ingles in Santa Cruz in the photograph. It is an example of a good practice. There is only one board with the name of a shopping centre placed on the facade of a building. The board is not illuminated during the night. There are no other boards placed on the facade of the building, e.g. with names of shops and trademarks available in the centre.

Figure 1, example 4: There is a bus stop in a village Chimiche. Chimiche is a small settlement with less than 1000 inhabitants. On working days, buses are scheduled in the village between 5:50 am and 8:40 pm on a bus routes from Granadilla to El Polis, from Granadilla to Santa Cruz, and from Granadilla to Güimar (bus routes 430, 116 in 035²). The bus stop is illuminated at night even though there is no bus scheduled in the night.

Figure 1, example 5: This photograph was taken in Tamaimo. There is a block of flats in the figure. The building is excessively illuminated, and consequently it is seen miles around. It looks like a mansion when it is seen from faraway. Of course, one should not forget that the area is included in the legislation for protection the environment from light pollution.

Figure 1, example 6: In the photograph there is an advertising board in Las Americas. These types of advertising boards can not only be found in the tourist south, but everywhere else on the island as well. In this case, there are several imperfections considering illumination. The board is white with black letters. Furthermore, the board itself is illuminated. The more acceptable solution would be white letters on a black background; the effect would be better and less light would travel into the sky. Now, the majority of the light from the board travels into the sky; the same effect would be achieved with illumination of the board from below to the top of the board. The best solution would be illuminating the board from top to bottom. In that case the board would be illuminated, not the sky. Only the light reflecting from the board would travel in to the sky. When advertising boards are placed next to the roadway, they draw attention of the drivers and consequently affect the traffic.

Figure 1, example 7: One of the hotels in Los Cristianos. The tourist area, that includes Los Cristianos, Las Americas, Costa de Adeje, and some other resorts, is Las Vegas in Tenerife. There the light gives the kitschy impression not the (false) impression of safety. Everything possible is illuminated: hotels, trees, fences, etc. What is more, white light is not an exception in illuminating these things. Huge boards with names of the hotels are illuminated with white light; they can be seen miles around and cause glare. Human eye is more accustomed to warm colours. Therefore, yellow light at night is more suitable for human eyes, and it does not cause as much glare as the white light. The lamps which emit in the blue part of the visible spectrum are more damaging for the environment³.

Monitoring sites



Figure 2: Map of night sky brightness monitoring sites (Source: http://mapas.owje.com/12059_mapa-topografico-de-la-isla-de-tenerife-2010.html)

There are 130 monitoring sites presented in the figure 2. The measurements were carried out from March to May 2012, using Sky Quality Meter (SQM). The Sky Quality Meter measures the night sky brightness in magnitude per square arc second ($\text{mag}/\text{arc sec}^2$). The higher the result of the measurement, the darker the sky. The lower results are a sign of a brighter sky, and therefore the higher light pollution. In each monitoring site the night sky brightness was measured three times in a row. Later the average result was calculated. Furthermore, in each site additional eight measurements in all directions in the sky were carried out.

The measurements were carried out considering all the limiting factors; they were carried out at night when there is no Moon in the sky. The latter would influence the results of the measurements with its glow. The waning crescent Moon rises in the second part of the night. Therefore, the measurements are carried out in the first half of the night when there is no Moon in the sky. At the time of waxing crescent Moon, the situation is the other way around. Furthermore, clouds also affect the results of the measurements; the light reflects from the clouds and returns to the Earth. The measurements carried out near lamps do not present the actual situation; in that case the brightness of a lamp is measured not the night sky brightness.

The average value of the night sky brightness in Tenerife is $19.23 \text{ mag}/\text{arc sec}^2$. In Anaga Landscape Park in northeast of the island, and in El Teide National Park in the central and northwestern part of the island, the values above $20 \text{ mag}/\text{arc sec}^2$ were measured. The values measured in the monitoring sites between the following settlements stand out: Nuenvista del Norte, Santiago del Teide, and San Juan de La Rambla; Izaña, Teleferico del Teide, Vilaflor, and Chio; and mountain path from Las Mercedes to San Andres. The higher values are a result of the fact that the northwestern part of the island is included in legislation against light pollution. The highest value measured was $21.33 \text{ mag}/\text{arc sec}^2$ in two sites in El Teide National Park: near Montaña Roja and Llano de Ucanca. The second highest value ($21.32 \text{ mag}/\text{arc sec}^2$) was measured near a cable car for Pico del Teide.

Lower values indicate brighter sky and higher light pollution, and were measured in the area that is not included in the legislation against the light pollution. The values lower than $17 \text{ mag}/\text{arc sec}^2$ were measured in the area of northern and southern motorway, and in the southern tourist part of the island. The values measured in the monitoring sites between the following settlements stand out: La Matanza and La Orotava; Radazul, San Miguel/San Isidrio, Playa de San Juan, and Arona; and in the two most attractive beaches Los Cristianos

and Las Americas. The lowest value measured in Tenerife was 15.08 mag/arc sec². It was measured in Güimar, near a town park which is illuminated at night. The proximity of the light sources is the reason for the low values of the measurements. The second lowest value (16.14 mag/arc sec²) was measured in Los Cristianos.

Photographs of Sky Glow in Chosen Sites in Tenerife



Figure 3: All-sky photographs of sky glow in chosen sites in Tenerife (Photo: Tanja Premoša)

All-Sky photographs present sky glow at night. The following are certain conditions to be fulfilled when taking photographs of a sky glow: night sky without clouds; no Moon in the sky, because it would additionally illuminate the sky, therefore the photograph would not be representative; no trees, houses or other objects near the site where a photograph is taken. Due to the diverse terrain, it was difficult to find an appropriate site for taking a photograph. In all-sky photographs and graphs of the night sky brightness in all sky directions, it is seen in which direction the sky glow is the most emphasized. The higher the sky glow is, the worse the light pollution is. The sky glow that reaches near zenith indicates a light source near the site where the photograph is taken. The closer the light source to the monitoring site is, the worse the light pollution. In the centre of the photograph is zenith where the proportion of the artificial light is smaller.

All-sky photographs were taken with digital camera Canon EOS 1100D and an improvised stand. The following settings were used: ISO sensitivity 1600, Manual mode, not using flash mode, manual setting of exposure value (180 seconds), and manual setting of aperture to the value $f/5.6$. The same settings were used in all cases; therefore the photographs can be compared.

In the figures 3 and 4 eight sites are marked where all-sky photographs were taken and night sky brightness was measured in all eight directions in the sky. The highest value measured in zenith among these eight was measured near a cable car for Pico del Teide in El Teide National Park; the value is $21.32 \text{ mag/arc sec}^2$. The value above 21 mag/arc sec^2 was measured in Buenvista del Norte as well. In these two sites the sky was the darkest; the measured values were higher than 21 mag/arc sec^2 in all eight directions in the sky. In Vilaflor a value measured was high as well; therefore the site is not heavily light polluted. The lowest value was measured in Arico ($18.85 \text{ mag/arc sec}^2$), and is followed by Mercedes, Humboldt and Güimar. In the last three sites the measured values were from 19 to 20 mag/arc sec^2 . In all-sky photographs it is clearly seen in which direction the sky glow is the most emphasized.

In the measuring site outside **Las Mercedes** (route to Anago) the sky is substantially polluted due to the light from Santa Cruz and La Laguna, the two largest cities south and southwest

from the monitoring site. In these two directions the values of the night sky brightness were the lowest, namely 18.64 mag/arc sec² in the direction of the south, and 19.11 mag/arc sec² in the direction of southwest. Due to the Anaga Landscape Park and dispersed settlement, the sky is darker in the direction of north, northeast and west.

From the viewpoint **Mirador de Humboldt** northern coast and city Puerto de La Cruz is seen during the day, and illuminated northern motorway is seen at night. Due to the illuminated motorway, the sky glow is the most emphasized in the direction from north to east. Even though the site where a photograph was taken is not in the immediate vicinity of the motorway, the photograph is brighter due to the traffic. Furthermore, the light that reflects from the ocean also contributed to the night sky brightness. Also the light from Santa Cruz and La Laguna cannot be neglected. In the direction of northwest and west, where the area is included in the legislation against light pollution, the night sky brightness is lower. However, the values of the night sky brightness in the mentioned directions are lower than expected, namely 19.50 and 19.76 mag/arc sec². The reason is illumination of the towns Puerto de la Cruz and La Orotava in the north.

In **Güimar**, the value measured in the zenith was 19.50 mag/arc sec². Due to the lower number of the light sources, the right side of the all sky photograph is not as illuminated as the left one. However, it is illuminated by the reflection of the light from the ocean. In the direction of northwest a sky glow is formed by the light from Puerto de La Cruz. In the direction of southwest and south, the sky is illuminated by the light from Granadilla and San Isidria. The values were below 19 mag/arc sec².

Compared to the other sites, in **Arico** the sky is the brightest. The monitoring site is located southeast from Arico. Due to the illumination of the settlement, the night sky brightness is the highest in the direction of northwest. The sky is the brightest in the direction of Granadilla, San Isidro, and El Medano. The highest values were measured in the direction of east, which is in the direction of the ocean, and in the direction of northwest, that is in the direction of El Teide National Park.

Vilaflor is the last settlement in the southern part of the island outside the El Teide National Park. The latter is included in the area protected from light pollution. The measures against light pollution are seen in all-sky photographs; the bottom half is brighter than the rest of the photograph. The light from the tourist south influences the brightness of the sky. The sky is the darkest in the direction of north because there are a few light sources. The value measured in the direction of north was 20.87 mag/arc sec².

Los Gigantes is one of the most attractive tourist resorts in the western part of the island. There the tourist can see the highest cliffs, which rise from 500 to 800 metres above the sea level. Despite the tourism, the sky is relatively dark since the area is included in the legislation against the light pollution. In the all-sky photograph, the sky glow in the southeast direction is seen. It is caused by the light from larger settlements in the west of the island, namely Guia de Isora, Adeje, Los Cristianos, and Las Americas. The photograph was taken southwest from Los Gigantes where there are no light sources. Therefore, the night sky brightness is higher in the direction of northwest, and it is a result of the light from Los Gigantes, and the light reflected from the ocean.

All-sky photograph was taken just outside **Buenavista del Norte**. The values measured were higher than 21 mag/arc sec² in all directions in the sky. The value of the night sky brightness in the direction of the south was 21.26 mag/arc sec², and in the direction of the north and northwest was 21.02 mag/arc sec². The reason for the higher value in the direction of the south is the Teno Massif which lessens the light intrusion from the south. The night sky brightness in the north and northwest is a result of the light reflected from the ocean. In the direction of east, the night sky brightness is a result of light from the cities Los Silos, and Garachico, and in the direction of northwest the sky brightness is a result of a light from Buenavista del Norte.

Light Pollution in all Directions in the Sky in Vilaflor and Las Mercedes

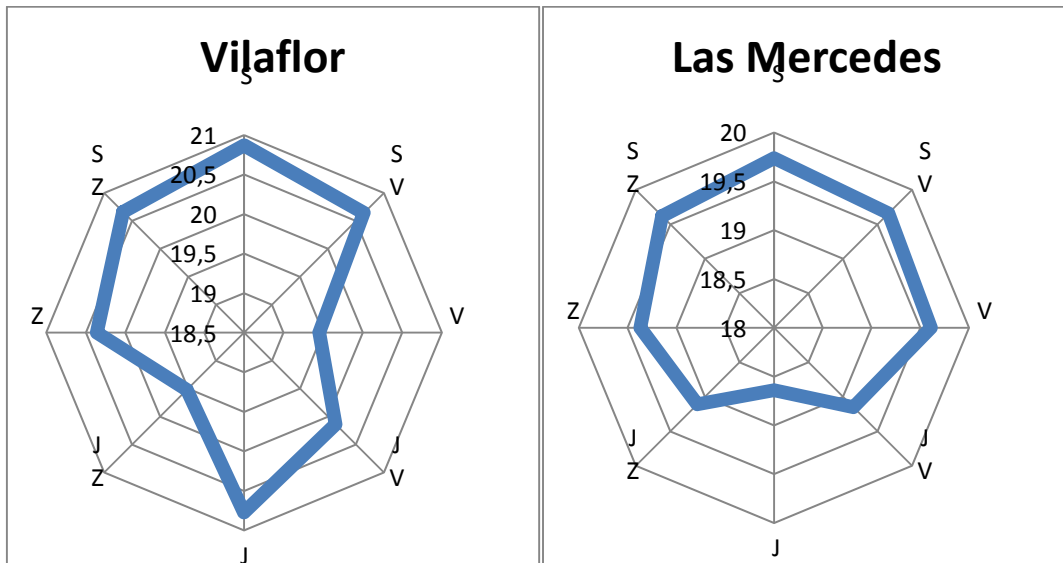


Figure 5: Graphs presenting light pollution in all directions in the sky in Vilaflor and Las Mercedes (Author: Tanja Premoša)

The graphs present light pollution in all eight directions in the sky. Lines closer to the centre of the polar graph present lower values measured, therefore higher light pollution.

There are two examples of the light pollution in all directions in the sky in the figure 5. The first measurements were carried out in Vilaflor, and the second were carried out in Las Mercedes. Vilaflor is situated in the south of the island, 18 kilometres from the main tourist resort Los Cristianos. Las Mercedes is situated in the northwest of the island, 5 kilometres from the second largest town San Cristobal de La Laguna, near Anaga Landscape Park.

In the graph for Vilaflor it is evident that the light pollution is the worst in the direction of east and southwest. The best result of the measurement was in the direction of north. The measurements were carried out in the vicinity of petrol station which was not illuminated. The highest value, 20.87 mag/arc sec², was measured in the direction of north, and the lowest value, 19.45 mag/arc sec², was measured in the direction of east. The latter value is a result of the sky glow in the direction of east, southeast, and southwest. The value measured in the direction of north is so high, because there is El Teide National Park and no settlements. The night sky brightness in the direction of north is a result of light from settlements in the northern part of the island. However, the light from the north is limited by Las Cañadas

caldera and El Teide peak. Night sky brightness southeast and southwest from Vilaflor is a result of a light from major tourist resorts, namely Adeje, Arona, Los Cristianos, and Las Americas in the southwest, Granadilla, San Miguel, and San Isidro.

The values of the night sky brightness in Las Mercedes were lower than in Vilaflor. The measurements were carried out just outside Las Mercedes, in the direction of Anaga Landscape Park. In all directions in the sky the values were lower than 20 mag/arc sec². The average value of the night sky brightness in zenith was 19.64 mag/arc sec². South from Las Mercedes the sky is the brightest due to the light from the two major towns, namely La Laguna and Santa Cruz. The value of the night sky brightness in the direction of south was 18.64 mag/arc sec². In all other directions in the sky the values were higher than 19 mag/arc sec². The highest value was measured in the direction of north since there are not many light sources there. However, it is important to emphasize the distance between the measuring site and light sources; light sources causing light pollution were closer to the monitoring site in Las Mercedes than in Vilaflor.

All-Sky Photographs of Sky Glow near El Teide peak



Figure 6: All-sky photograph near a cable car station for El Teide peak (Photo: Tanja Premoša)

The photograph was taken in the nearest viewpoint of the cable car to El Teide peak at a height of 2312 metres. The sky glow would not be seen as well, if a photo was taken in the vicinity of El Teide peak (in the car park near cable car). Due to the obstacles, the horizon there cannot be seen well. The site where a photograph was taken is 50 kilometres from towns Los Cristianos and Las Americas, and from 55 to 65 kilometres from towns Santa Cruz and La Laguna. These distances are the evidence that the light cannot be limited.

In this site the second highest value was measured, that is 21.31 mag/arc sec². This site is an area with the darkest sky in the island. In the north, there is El Teide peak, and in the east and west there is Las Cañadas caldera. The darkest sky is in the direction of north and northeast. There is at a height of 3718 metres El Teide peak, which to some extent prevents spreading the light from north and northeast. The caldera is at the lower height than El Teide peak, therefore the light from other directions can spread in the hinterland. A sky glow from Arico and Granadilla is seen, and from west and northwest is seen. There are the largest settlements in the western part of the island, namely Santiago del Teide, Los Gigantes, and Guia de Isora. The value of the night sky brightness in the direction of a crater of a volcano was 21.30 mag/arc sec², and in the direction of northeast the value was 21.43 mag/arc sec². Sky glows are higher in the eastern part of the island than in the western part. The reason for that is a higher number of light sources in the west of the island. However, an important fact is that the western part of the island is included in the legislation for protection against light pollution. This is the reason for a lower number of light sources and consequently less light emitted. These facts were all confirmed with the values of the night sky brightness. In the direction of southeast the value that was measured was 21.17 mag/arc sec², and in the direction of Los Gigantes the value was 21.20 mag/arc sec².

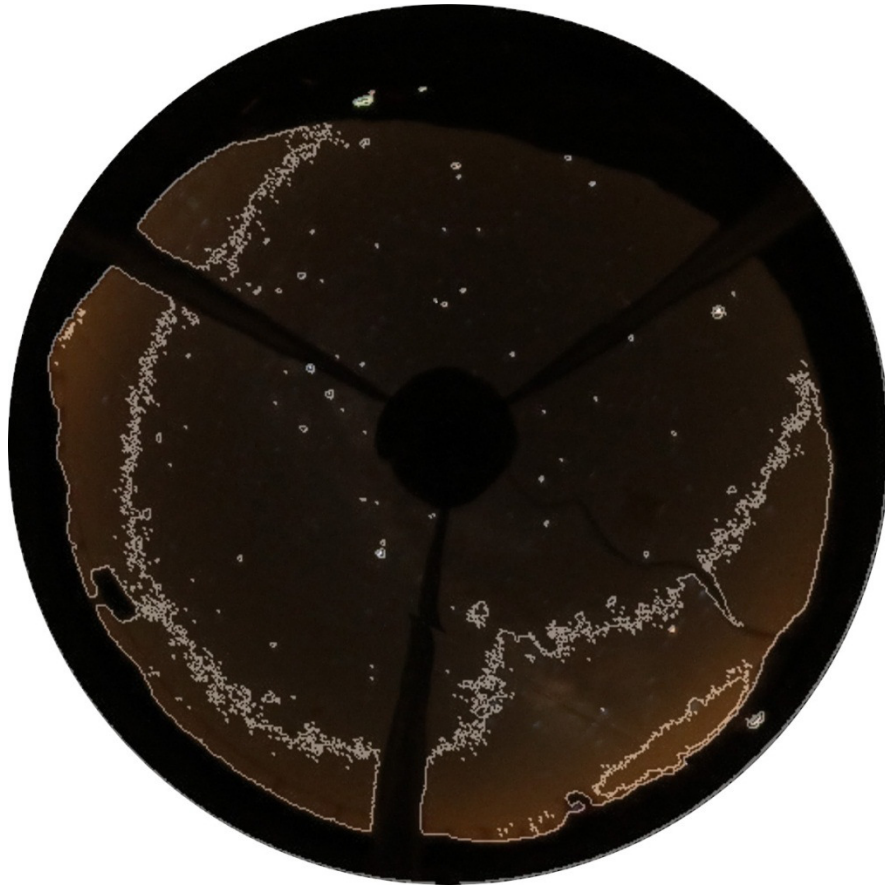


Figure 7: All-Sky photograph with isophotes near a cable car station for El Teide peak (Photo: Tanja Premoša)

Isophotes are lines used to present constant light intensity. In the figure 7 the sky glow is in all directions in the sky substantially distant from zenith. The sky glow in the direction of southeast is the highest and closest to the zenith. The sky glow in the west is also emphasized. The lowest sky glow is in the direction of north and northeast. In all other directions the sky glow is not particularly emphasized.

It is estimated that in the direction of the east, the sky glow is 10 % above the horizon, and in the direction of southwest 15 % above the horizon.

Light Pollution in Tenerife

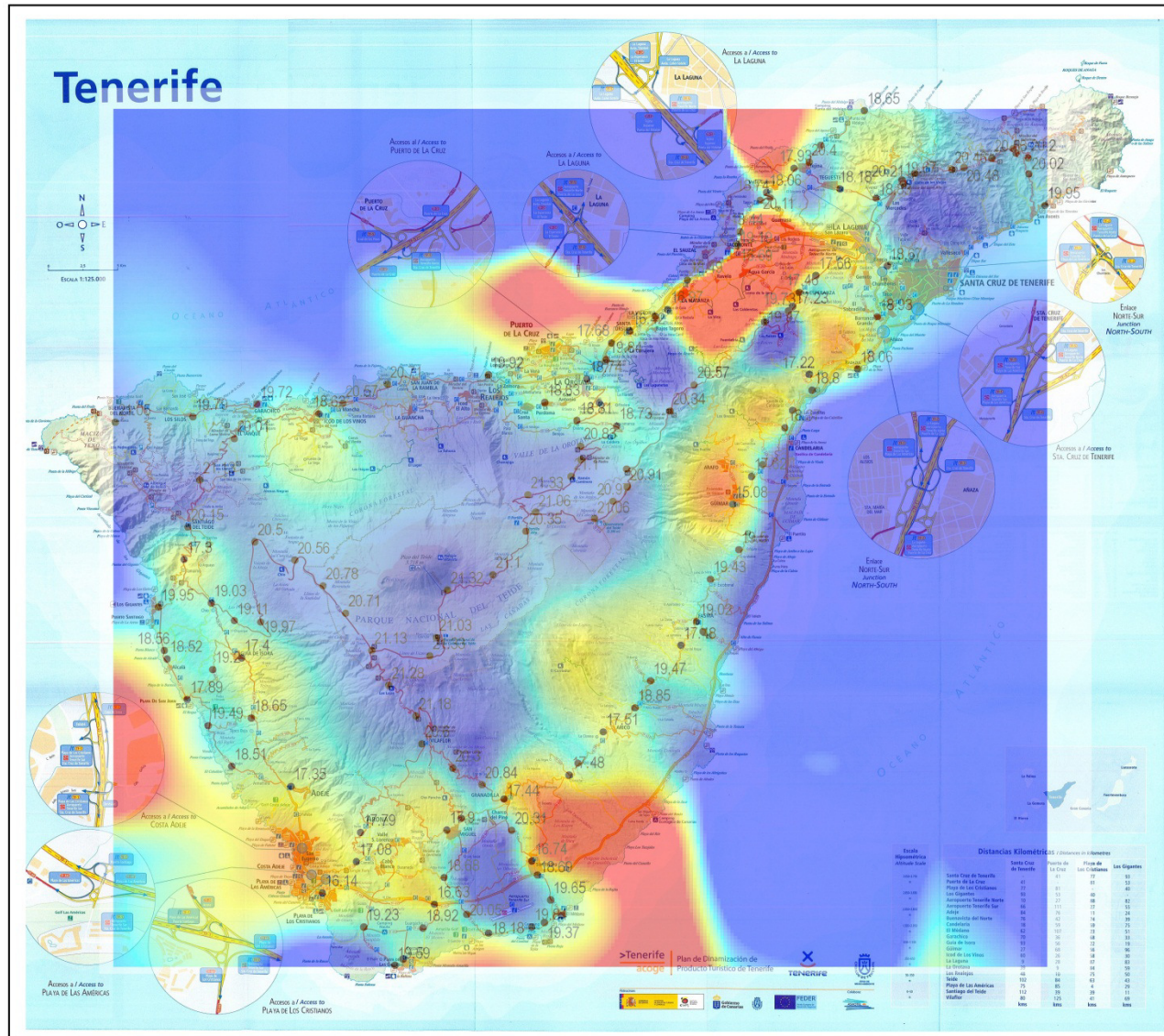


Figure 8: Map of light pollution in Tenerife (Cartographer: Igor Žibera)

Areas marked with red colour are more light polluted, and areas marked with blue have a darker sky. There are two major polluted areas; in the northeast of the island and in the southern part, that is in the southeast and southwest of the island. The most light polluted areas are not included in the legislation against light pollution. In these areas the measured values were mostly lower than 19 mag/arc sec². There are no boundaries for light. Therefore, unsuitable illumination and excessive illumination influence the areas outside towns and tourist resorts. The light is only limited by the Earth's curved surface and diverse terrain. The lowest values of the night sky brightness, excluding northwestern part of the island, are in the area of Las Cañadas caldera. The elevation rises with the growing distance from the ocean. The light is only limited by the caldera. Its diameter in the east-west direction is 17 kilometres, and in the north-south direction 9 kilometres. The sky glow does not form above the caldera due to its height, but a part of the light does reach the peak. The values of the night sky brightness within the caldera were not higher than 20.50 mag/arc sec².

In the northeastern part of the island the highest sky glow is in the area above the following towns: Santa Cruz de Tenerife, La Laguna de San Cristobal, and Puerto de La Cruz. That is due to the inappropriate use of lights, and excessive illumination. Furthermore, the majority of the population in Tenerife lives in these three towns. A part of the northern motorway, which is not included in the legislation against light pollution, is illuminated excessively on both sides of the road as well as all exits are illuminated.

In the southern part of the island two areas of light pollution formed. The southern part of the island is known for its diverse tourist offer. Hotels have large advertising boards that are seen from faraway. Furthermore, these boards are illuminated with white light which reflects and causes more glare than yellow light. What is more, advertising boards, trees, and streets are illuminated at night which gives a kitschy impression of the towns. Advertising boards with white light cause glare in a large area as well.

Conclusion

According to the results of the measurements that were carried out, three areas are excessively light polluted. These areas are in the northeast, northwest, southeast, and southwest of the island. The most polluted area in the northeast of the island is above the two largest towns in northeast, namely Santa Cruz and La Laguna, and above the largest town in north, that is Puerto de La Cruz. In the year 2011 more than 45 % of the population of Tenerife lived in Santa Cruz and in La Laguna⁴. The other two most polluted areas in Tenerife are in southeast and southwest of the island. There the majority of tourist resorts are situated. The largest towns, such as Los Cristianos, Las Americas, Costa de Adeje, and others literally invite tourist with its glare. The majority of the inhabitants in these towns are presented by tourists; mild climate is appropriate for tourism throughout the entire year.

Minor areas of light pollution are formed in the vicinity of northern and southern motorway, mainly near major towns such as Santa Cruz, La Laguna, and Güimar, as well as around tourist areas.

The measurements confirmed that the most light polluted areas are tourist areas, and areas where the majority of population live. The light pollution is the lowest in the areas included in the legislation against light pollution. However, sky glows from largest towns are seen in these areas, but the night sky brightness is not as emphasized as in areas not included in the legislation.

The sky will be darker, when the measures against light pollution are in use in other parts of the island as well. The darker sky will contribute to the better quality of astronomical observations, some species will be less endangered, the influence of light on human health will be reduced, the consumption of energy will be lowered, and what is more, our cost will be reduced. Therefore, it is essential to answer the following questions. Do we really need to illuminate everything? Do we illuminate things correctly? Do we need illumination all night?

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¹Source: <http://www.iac.es/otpc>

²Source: <http://www.titsa.com>

³Source: www.temnonebo.org

⁴Source: <http://www.gobiernodecanarias.org>

