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Measuring night-time urban heat island. Still a pending issue

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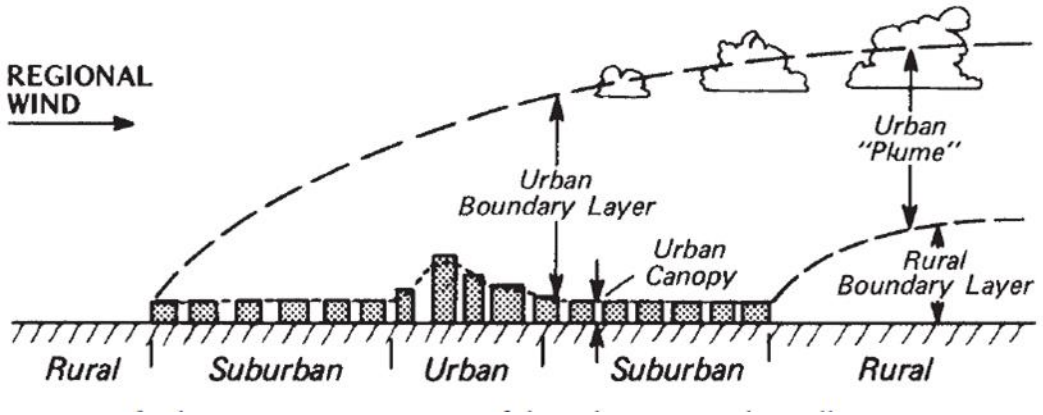
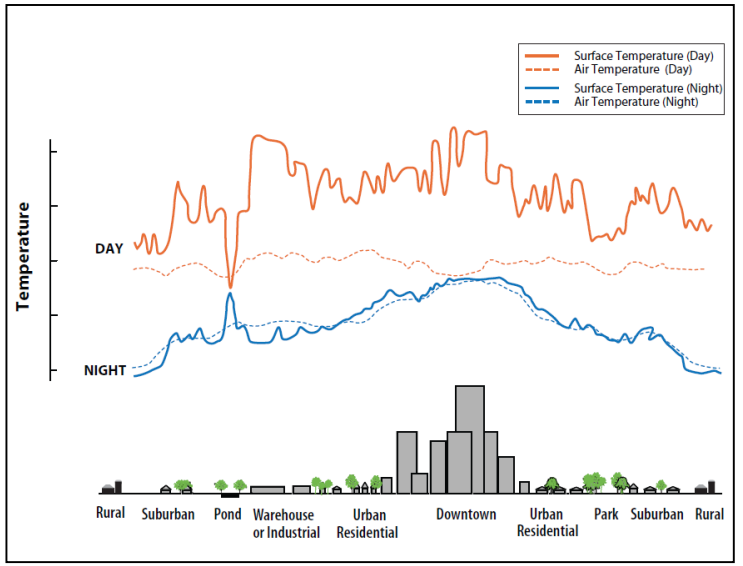
Urban Heat Island

The study of urban heat island (UHI) is of great relevance in the context of climate change (CC) and global warming

Cities accumulate heat in urban land covers as well as in built infrastructures, representing true islands of heat in relation to their rural environment, less urbanized.





LST & UHI

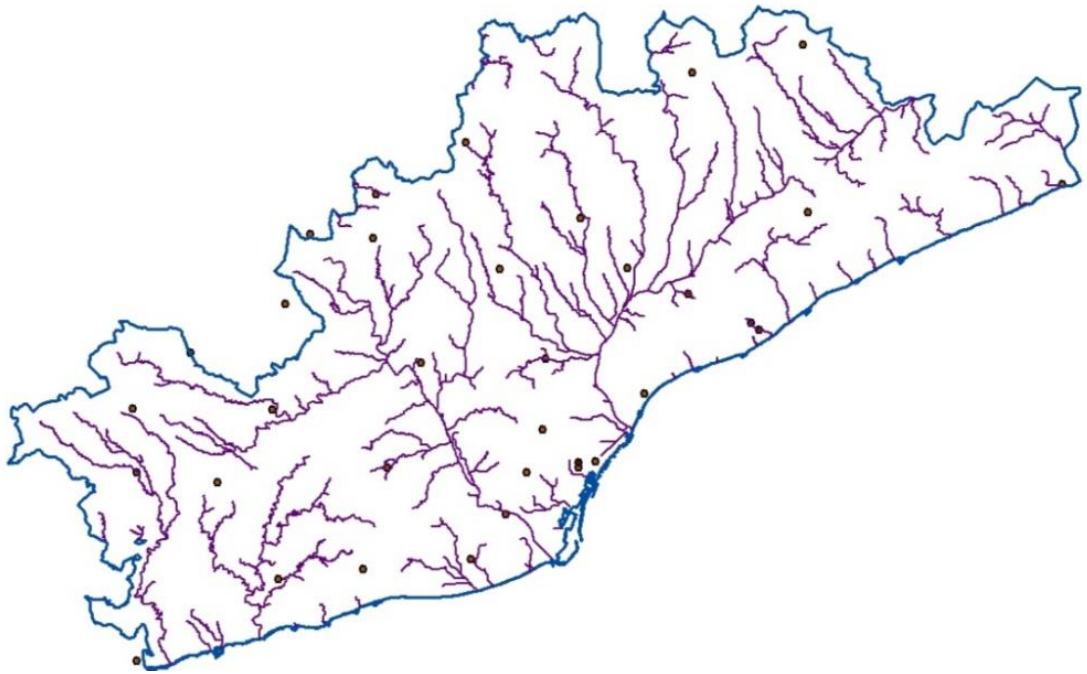
- There is a wide consensus that **Land Surface Temperature (LST) plays a key role in the generation of the Urban Heat Island (UHI)**, representing a determining factor in terms of surface radiation and the interchange of the energy, in addition to controlling the distribution of heat between the surface and the atmosphere

- **The composition of land covers are one of the main factors that influence the LST**

- Specialized literature has emphasized that **built up area** and **pervious surface** (occupied areas provided with vegetation) and **impervious surface** (paved and built areas) **have a significant impact on the generation of a UHI**. In this sense, the reduction of vegetation affects not only in an increase of the LST, but also the reduction of precipitation and evapotranspiration. The relationship between the LST and the Normalized Difference Vegetation Index (NDVI) is especially well- documented.

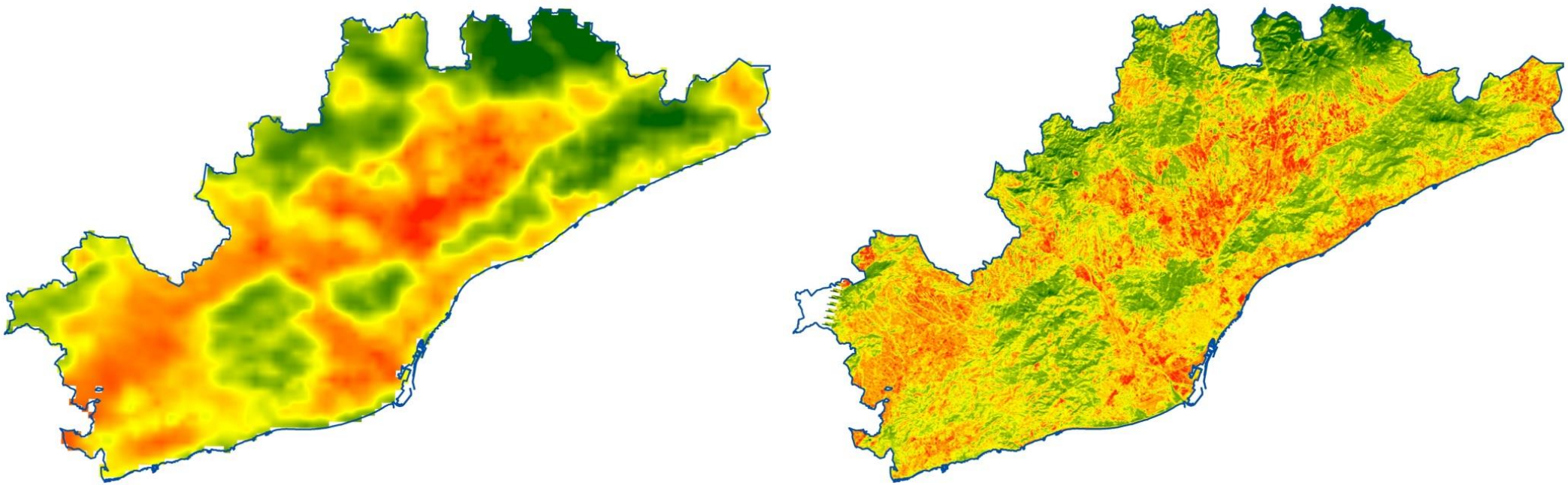
From the LST to LSAT

- Even though thermal sensors installed on planes and satellites permit the easy measurement of LST, UHI phenomena have been commonly studied using the air temperature in the atmospheric surface layer, usually at a height of 2 meters above the ground (land-surface air temperature, LSAT). The temperature of the air, when measured in weather stations, is one of the observations most frequently registered, with great precision and resolution over time.
- However, **the data obtained from weather stations are too general**, which in general terms means that they **do not efficiently represent the spatial variation of air temperature at an intra-municipal or neighbourhood level**. At the MRB (Metropolitan Region of Barcelona, 3,200 km^2, 4.8 millions inhabitatnts) there are only 33 weather stations



Limitations for measuring the UHI

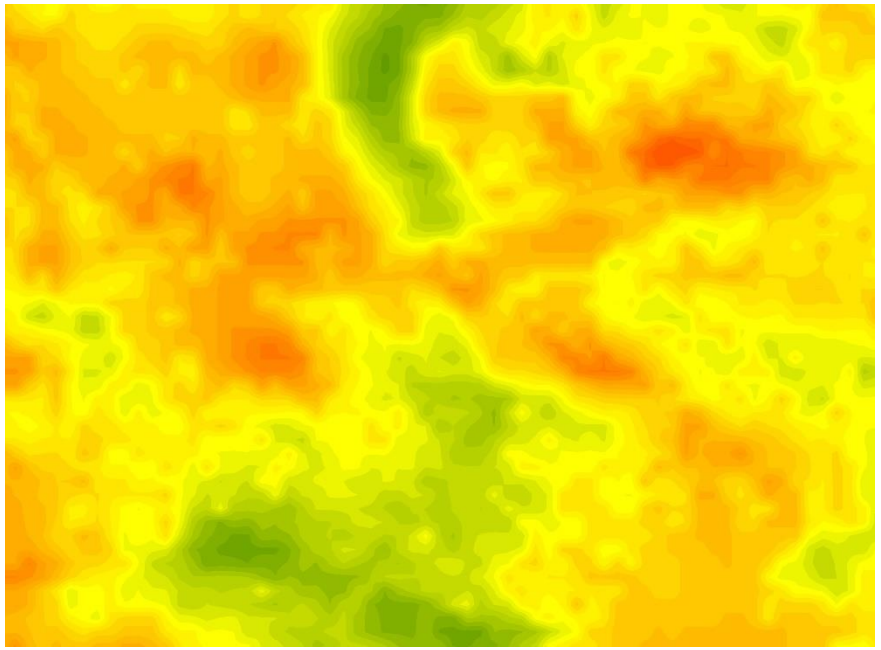
The availability of data at the appropriate scale is also an important problem. Even though the heat sensors installed on satellites, especially MODIS and LANDSAT are free and allow an easy measurement of LST, the information derived from them usually has a "grain" **that is too large for detailed analysis**, especially at an intra-urban level. In the case of MODIS, this is 1 km^2 per pixel, clearly insufficient for a detailed analysis. LANDSAT, with a pixel of 100x100 meters, allows a more accurate analysis, but is still insufficient

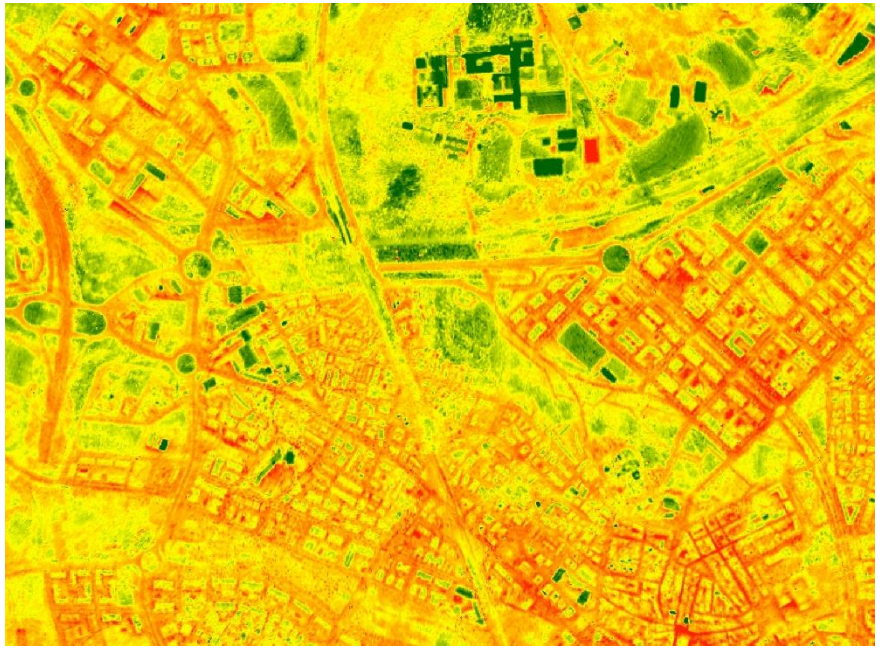


Limitations for obtaining Data from Aerial Sensors

- There are higher resolution images, taken with thermal sensors on airplanes, but these are not for free.
- In the case of some areas of Catalonia, the Cartographic Institute of Catalonia (IGCC) possesses airborne resources that capture thermal data at a high resolution, but is not open data
- The research has therefore been restricted to the use of average resolution satellite images (Landsat)

Landsat8





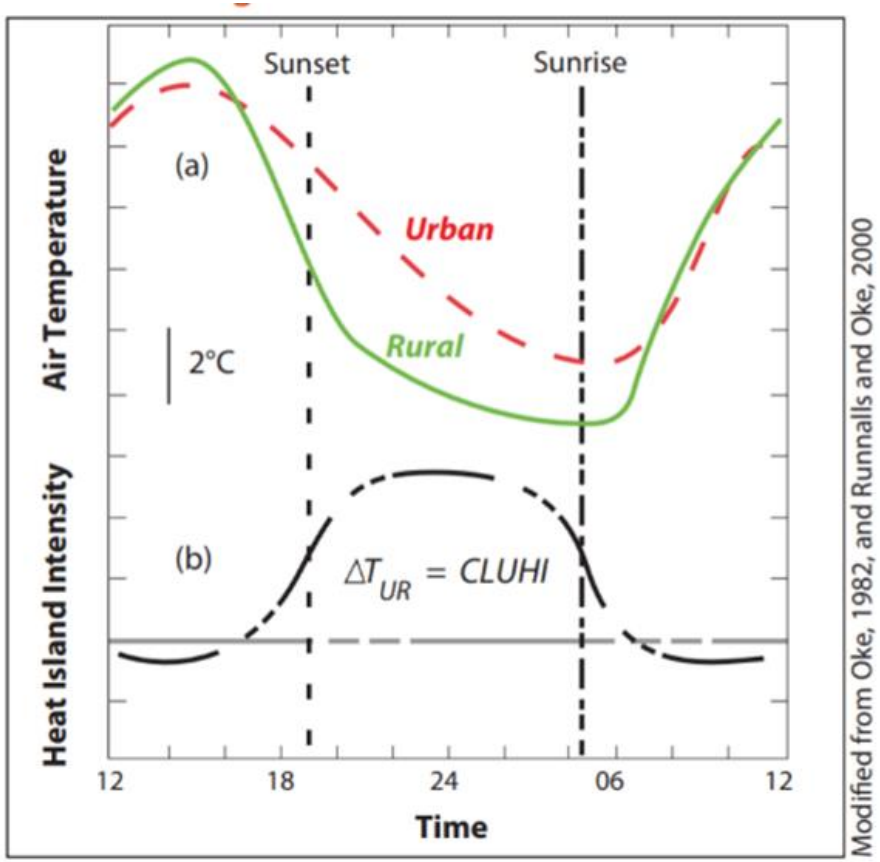
IGCC

Daytime and Nighttime Temperatures

- Another problem that exists in the measurement of the UHI consists in available nighttime thermal information: **Urban Heat Islands emerge at night above all**

- It is during the night that the effects of UHI become more apparent, due to the low cooling capacity of urban construction materials and is during nighttime that temperatures can cause higher health risks, leading to the aggravation of negative impacts on people's health and comfort in extreme events such as heat waves becoming more and more frequent and lasting longer

- However, the study of nocturnal UHIs is still poorly developed due to the structural problems regarding the availability of land surface and air temperature data for night time



Modified from Oke, 1982, and Runnalls and Oke, 2000

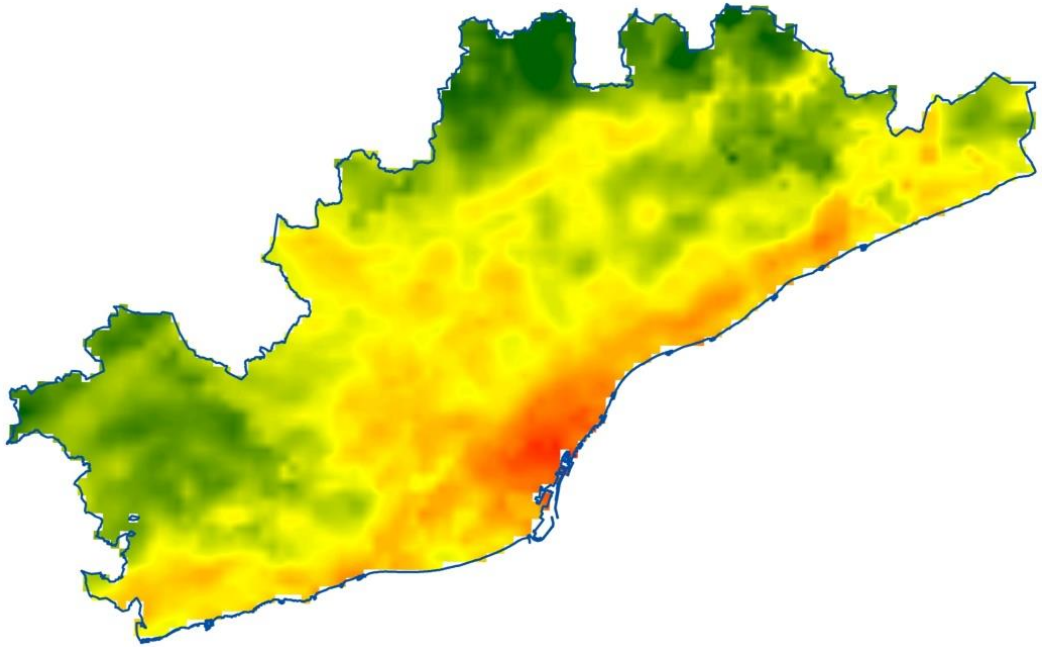
Nighttime Temperature

Traditional methods for obtaining nocturnal UHI have been directed either to extrapolation of data from weather stations, or obtaining air temperatures through urban transects

- In the first case, the lack of weather stations in urban landscapes makes it extremely difficult to obtain data to extrapolate and propose models at a detailed resolution scale
- In the second case, there is a manifest difficulty in obtaining data simultaneously and significantly representative of urban and rural zones

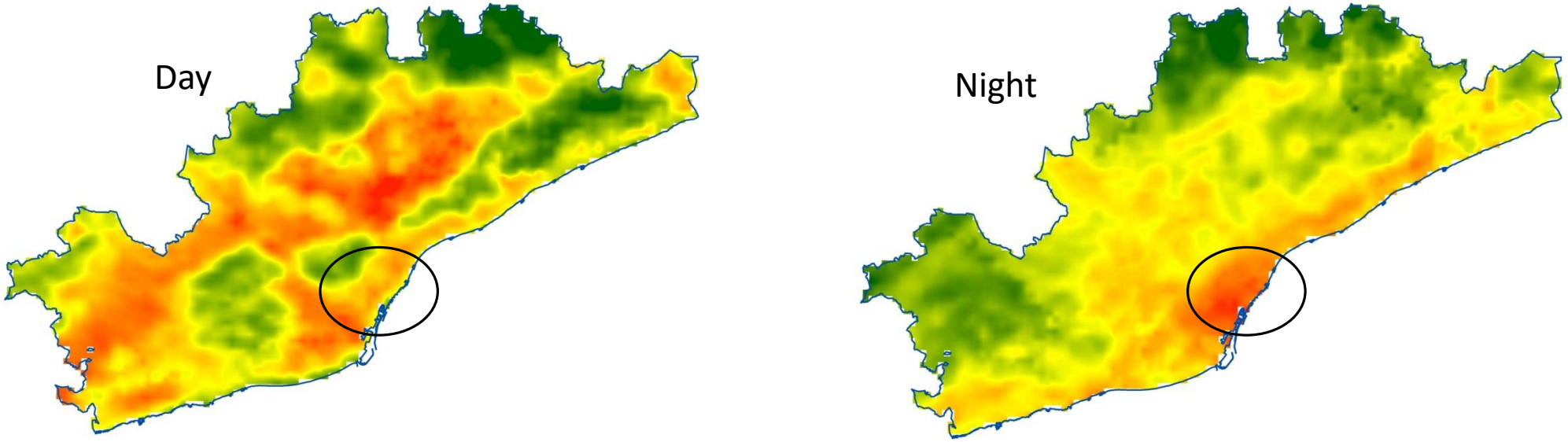
Another used methodology for measuring the nocturnal UHI is to use remote sensing, but the sensors that provide free information (LANDSAT) do not provide nighttime information

MODIS does!!



But the greatest limitation about this method is the low resolution, therefore it is clear the need for open source databases with better or higher resolution to quantify the night surface temperature

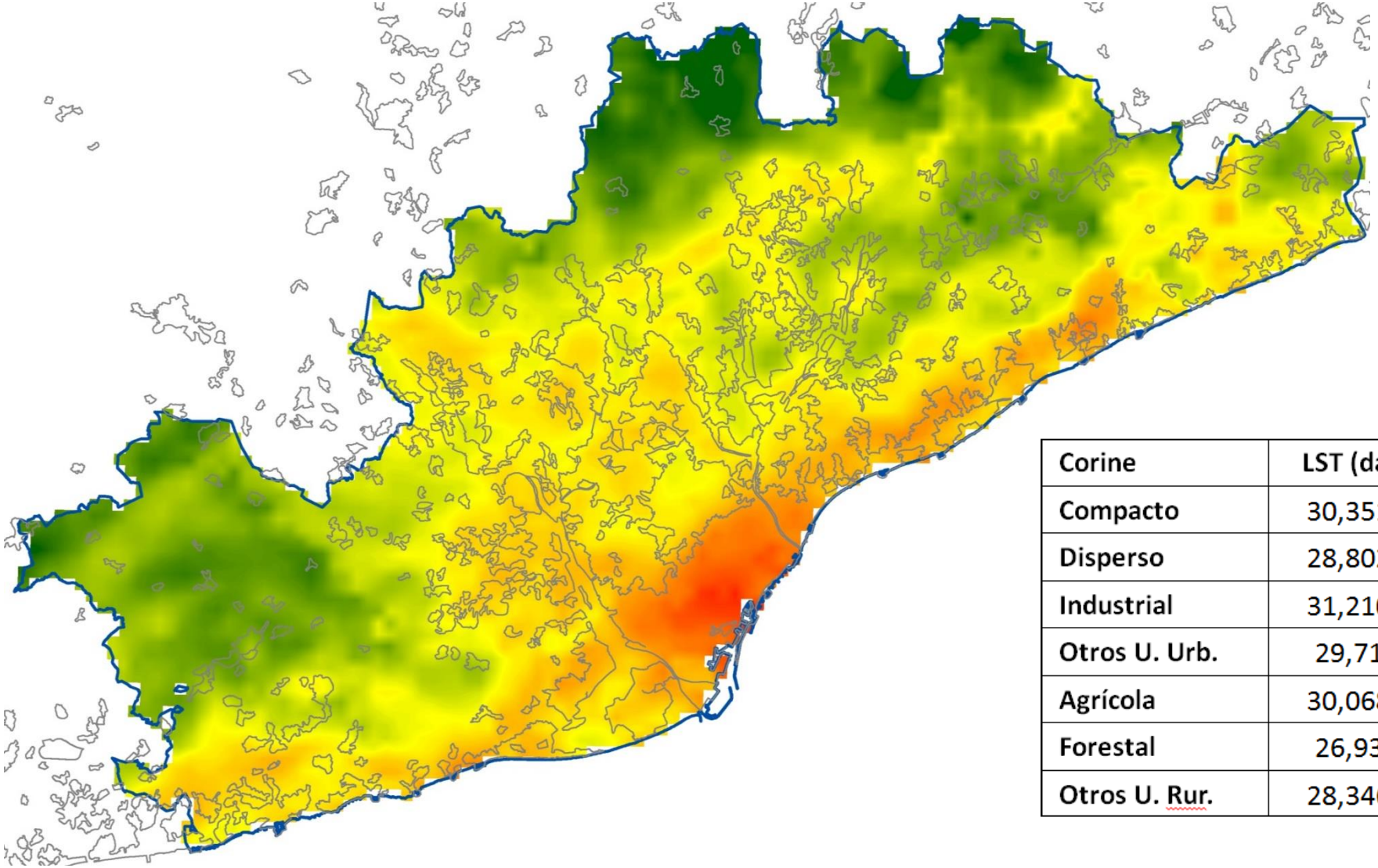
LST: Daytime and Nighttime Differences (MODIS)



Night-time LST has usually been studied through MODIS

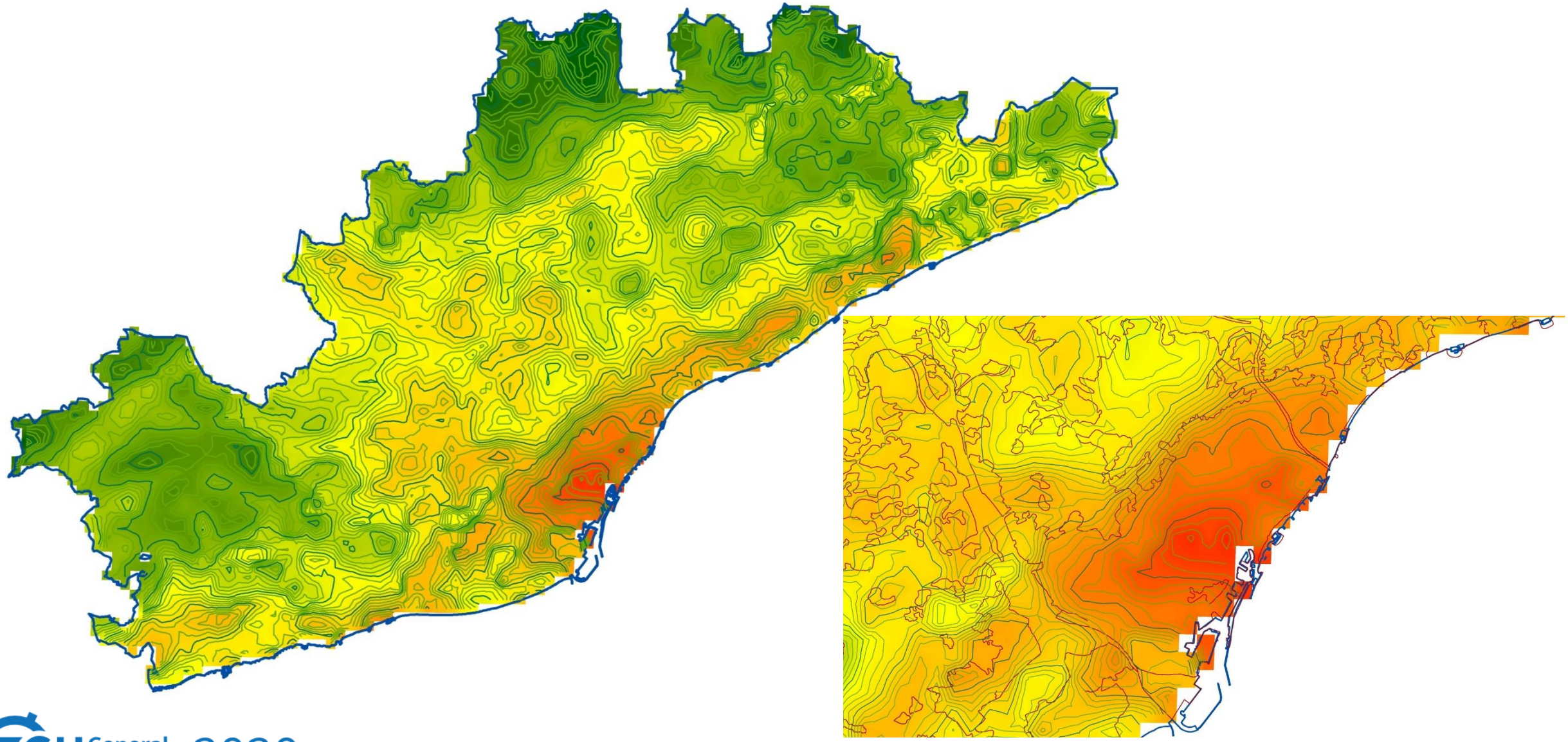
In the case of the Metropolitan Region of Barcelona (MRB) the night UHI is clearly observed in the city of Barcelona

Modis Night by Corine Land Cover (CLC, 2012)



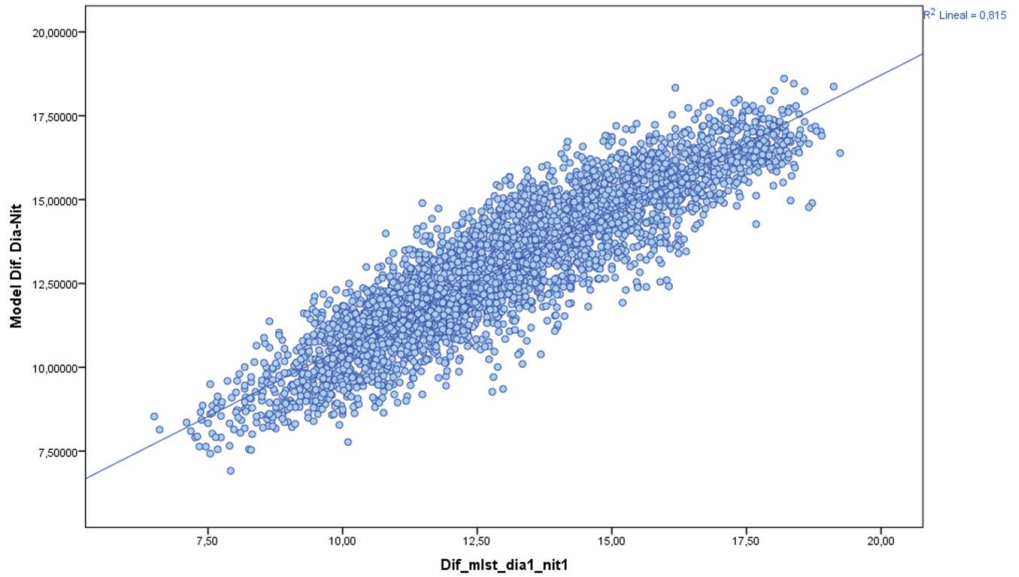
Corine	LST (day)	LST (night)	Diferencia
Compacto	30,3514	17,62809	12,72331
Disperso	28,8026	16,17281	12,62979
Industrial	31,2106	16,51994	14,69066
Otros U. Urb.	29,716	17,05805	12,65795
Agrícola	30,0684	15,06178	15,00662
Forestal	26,934	15,23426	11,69974
Otros U. Rur.	28,3466	15,32152	13,02508

UHI (LST night) by MODIS



Model: Difference between Day and Night (Modis)

- A first exercise to improve the spatial resolution of MODIS has been to perform an OLS model with night cooling as a dependent variable
- The model allows explaining 81.4% of the variation of the LST night cooling
- Said model, applied to the information provided by Lansat 8, has allowed to visualize the nighttime UHI with a resolution of 30 meters



Resumen del modelo[b]

Modelo	R	R cuadrado	R cuadrado ajustado	Error estándar de la estimación
1	,903[a]	,815	,814	1,06122

a. Predictores: (Constante), NDBI, Altres Rurals, Dist_costa, Orientació, Altres Urbans, Dist_Centre, Dispers, Industrial, Compacte, Pendent, MLST_dia1, Agrícola, DTM, ndvi_30, Forestal

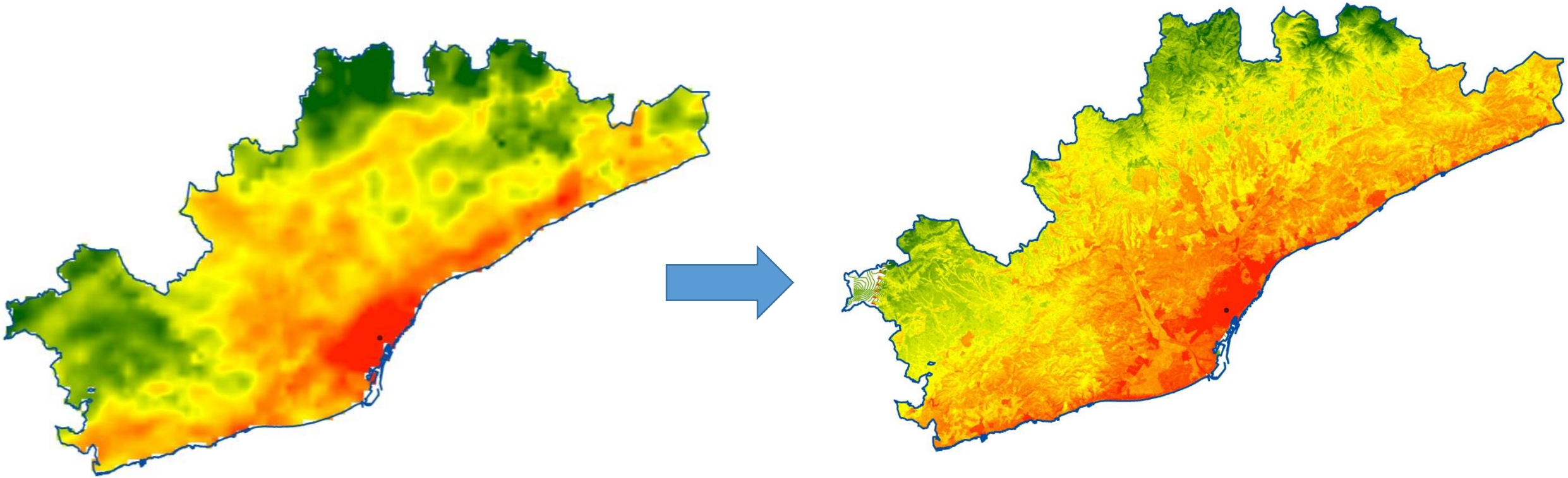
b. Variable dependiente: Dif_mlst_dia1_nit1

Coeficientes[a]

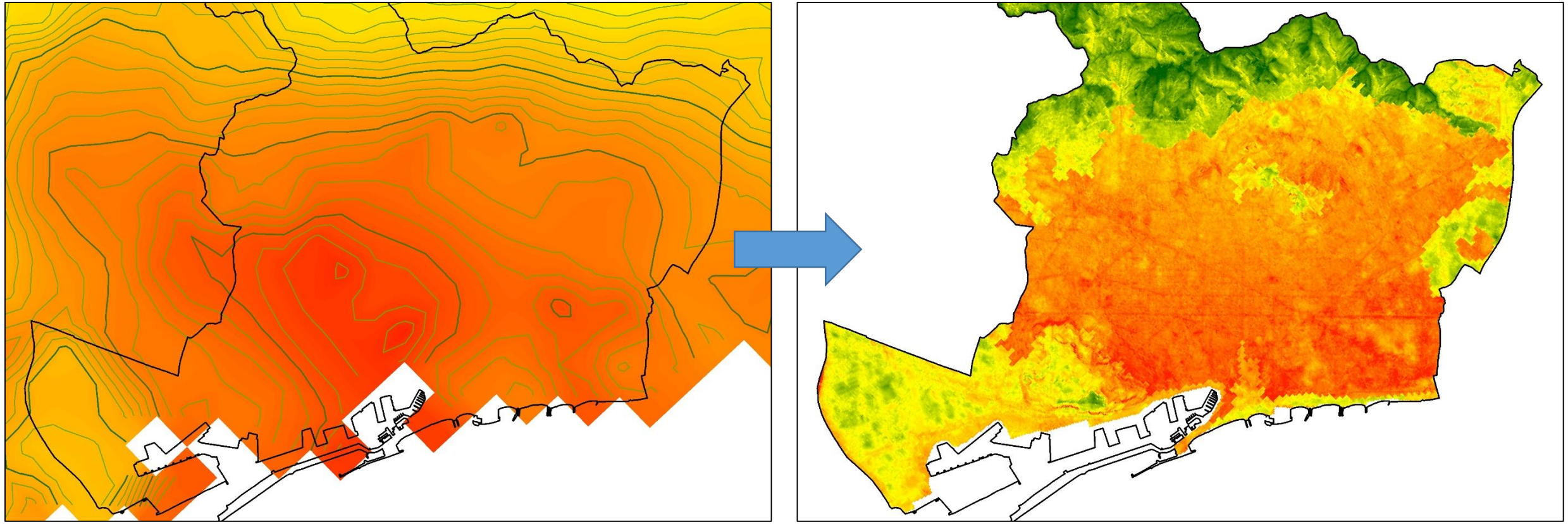
Modelo		Coeficientes no estandarizados		Coeficientes estandarizados	t	Sig.
		B	Error estándar	Beta		
1	(Constante)	-22,893	,643		-35,595	,000
	DTM	,004	,000	,362	26,362	,000
	Orientació	,001	,000	,029	4,068	,000
	Pendent	-,013	,001	-,104	-11,240	,000
	ndvi_30	1,627	,219	,107	7,428	,000
	MLST_dia1	1,130	,015	1,021	76,973	,000
	Compacte	-,471	,481	-,046	-,978	,328
	Dispers	,385	,478	,046	,805	,421
	Industrial	,411	,484	,034	,849	,396
	Altres Urbans	,176	,489	,011	,359	,719
	Agrícola	1,250	,477	,227	2,620	,009
	Forestal	,842	,477	,163	1,765	,078
	Altres Rurals	,710	,478	,102	1,485	,138
	Dist_costa	4,284E-5	,000	,172	17,212	,000
	Dist_Centre	1,681E-5	,000	,087	11,624	,000
	NDBI	1,538	,211	,098	7,290	,000

a. Variable dependiente: Dif_mlst_dia1_nit1

LST (MODIS night, model MODIS night 30 meters/pixel)

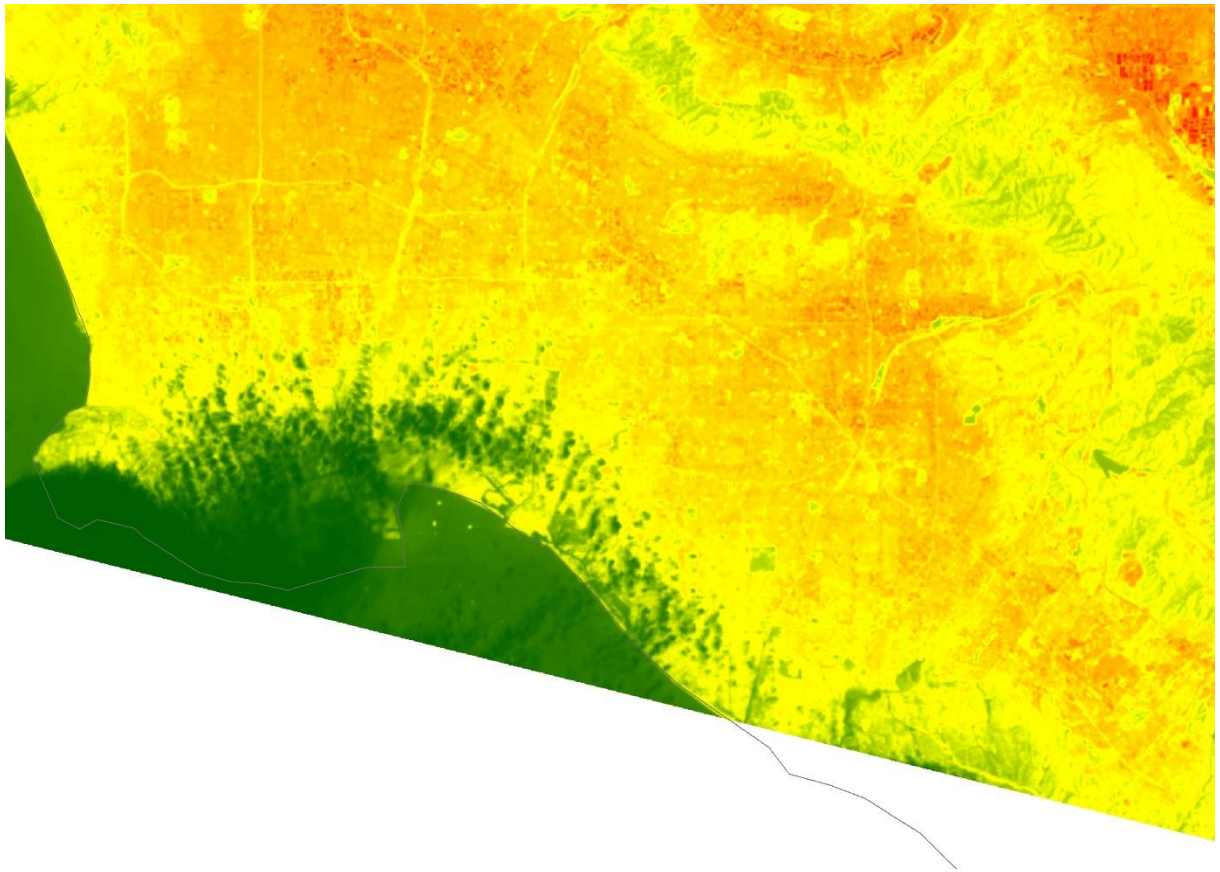


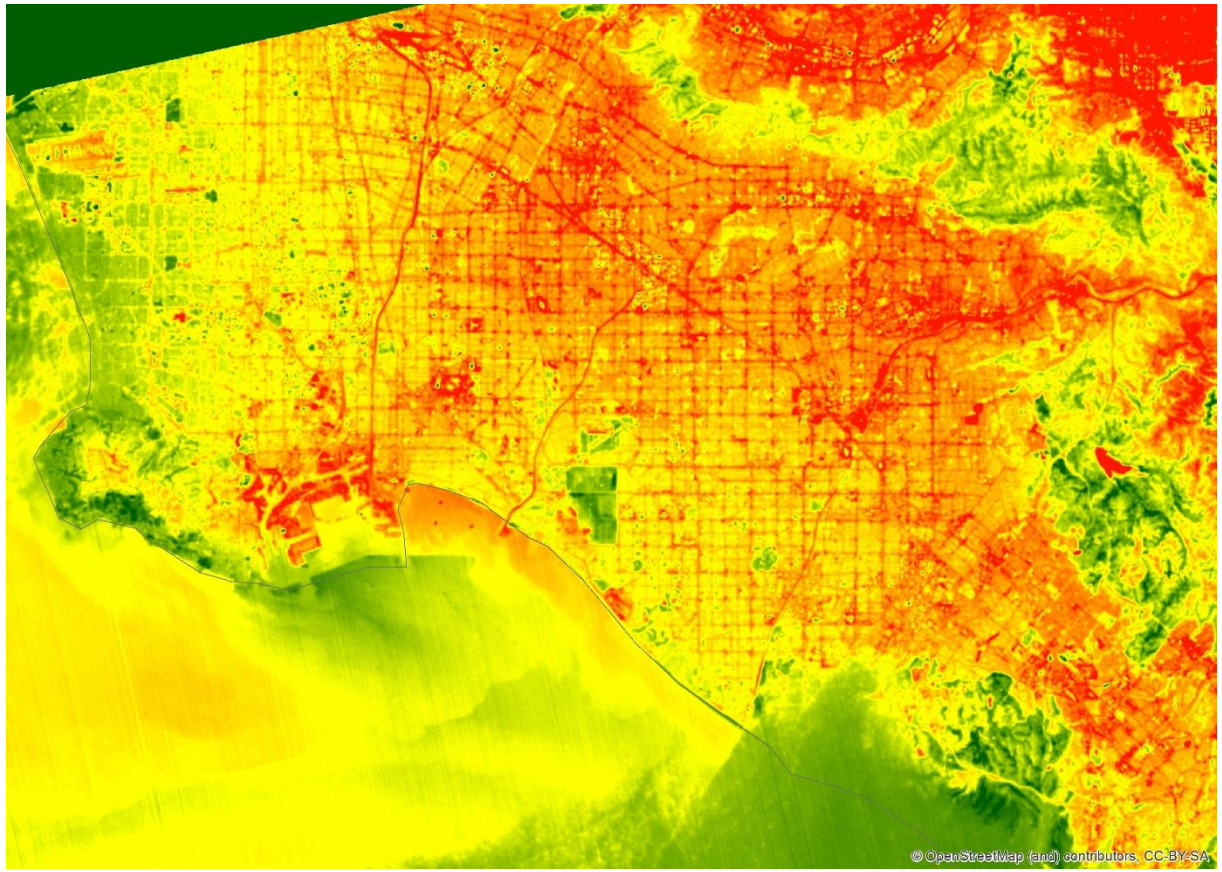
LST (MODIS night, model MODIS night 30 meters/pixel)
City Center



City of Barcelona
100 km²
1.6 millions inhab.

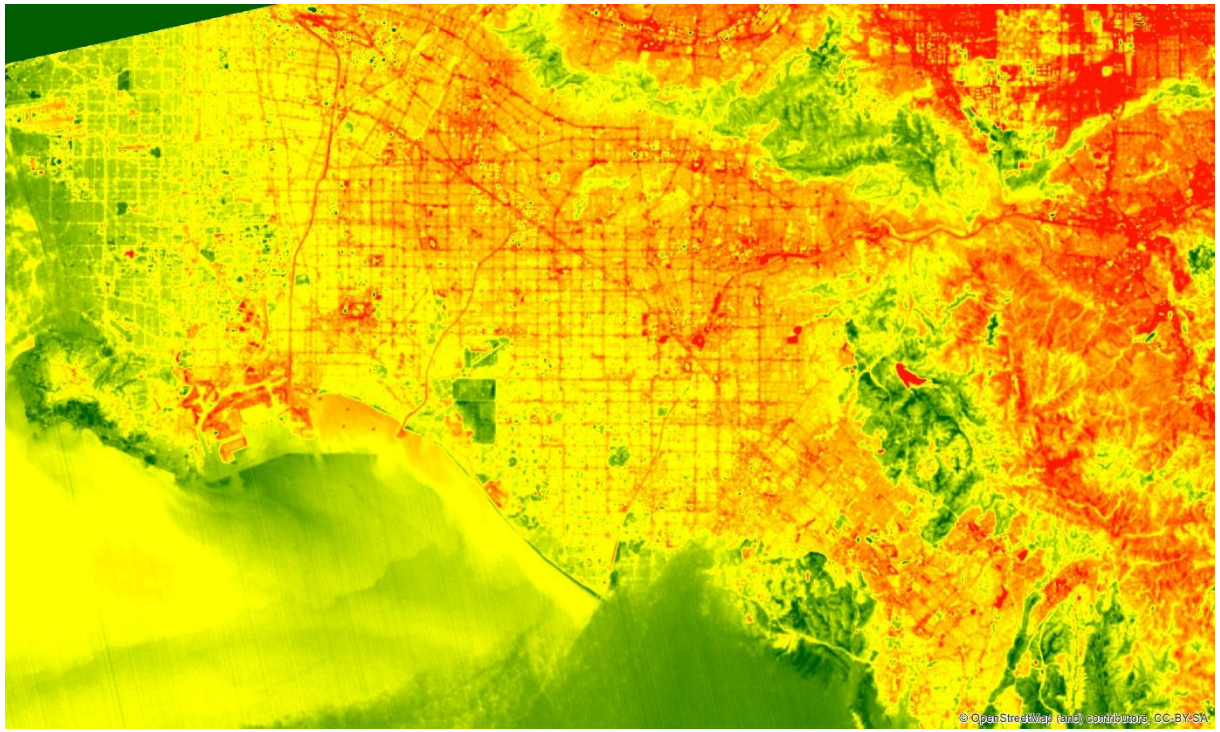
Landsat 8 b10: day/night

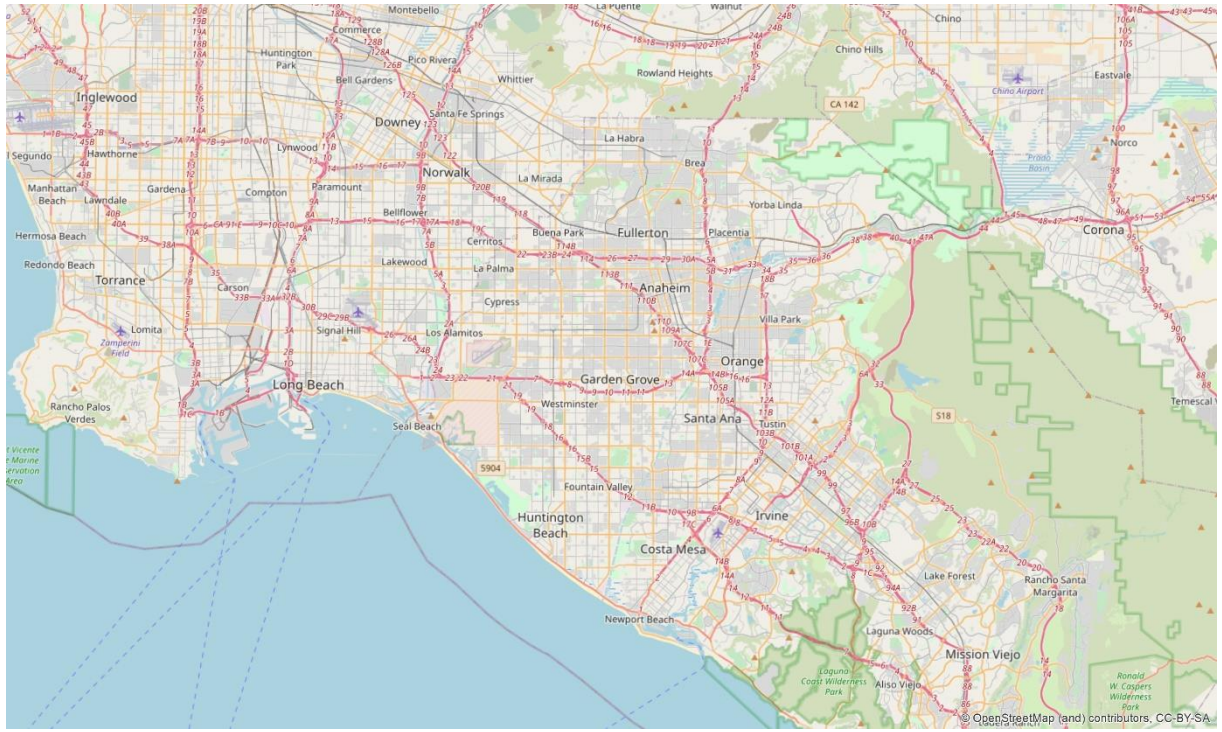




1:300,000

Landsat 8 b10: Los Angeles (7/16/2019; 5:42 h)





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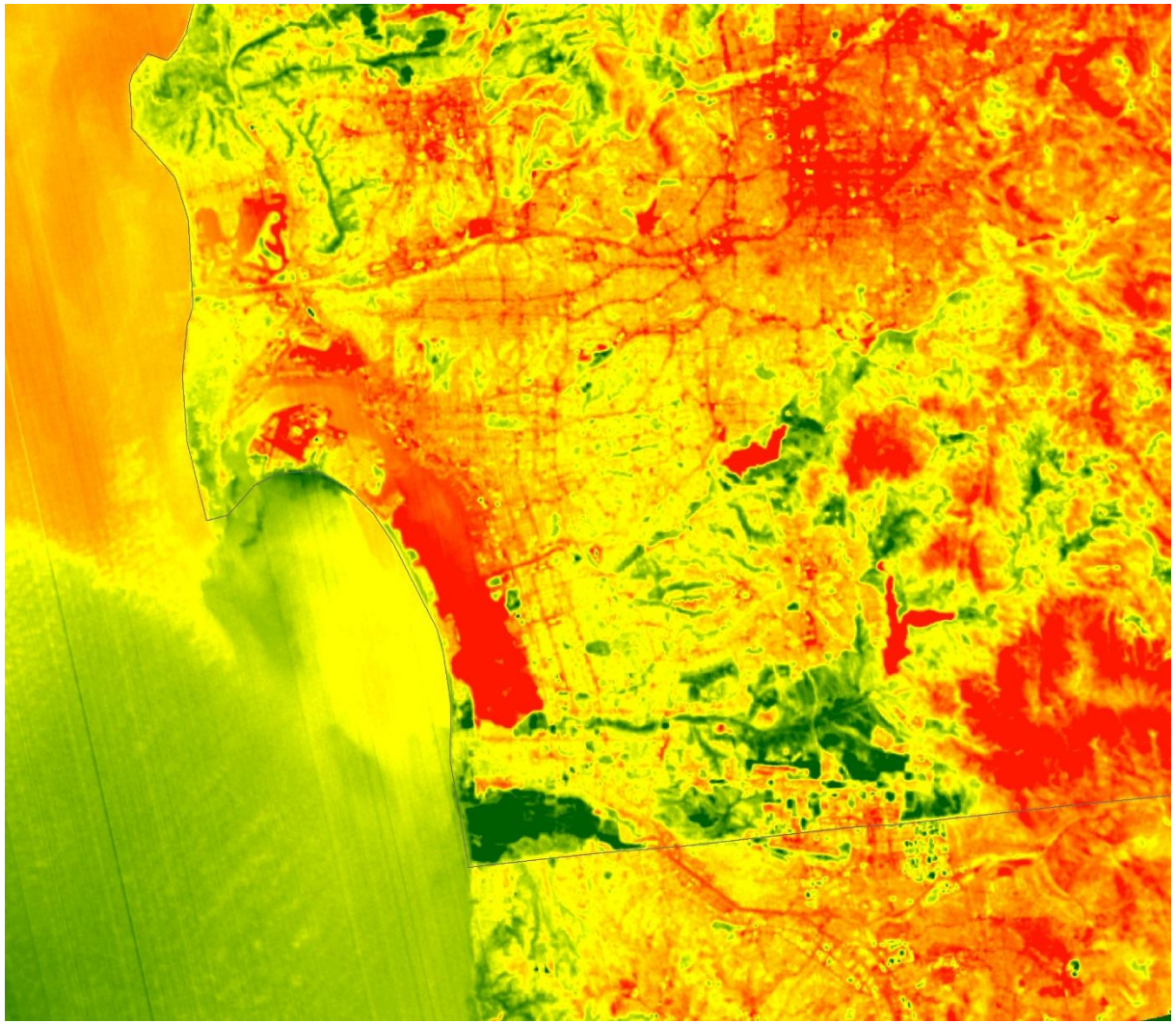
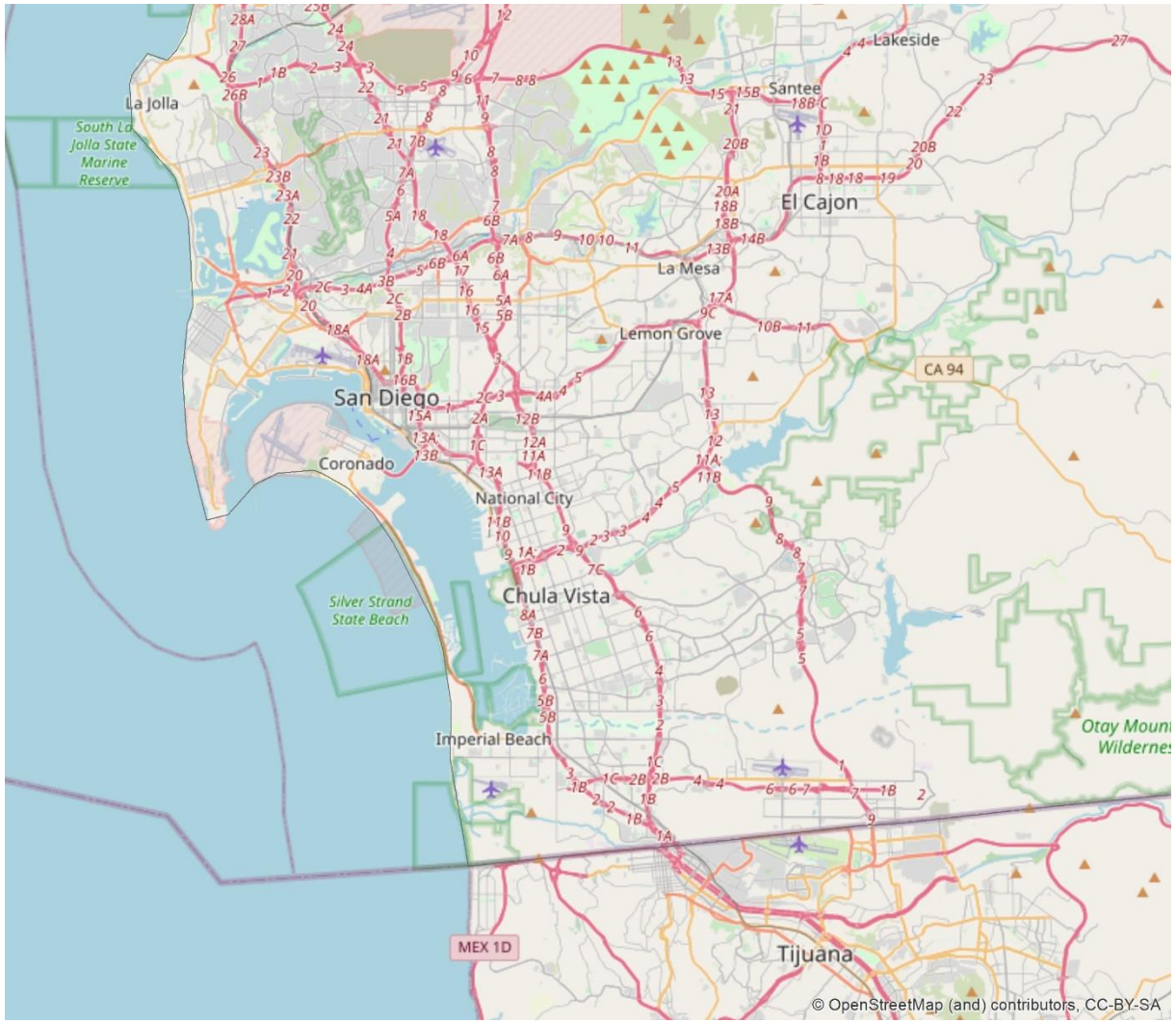
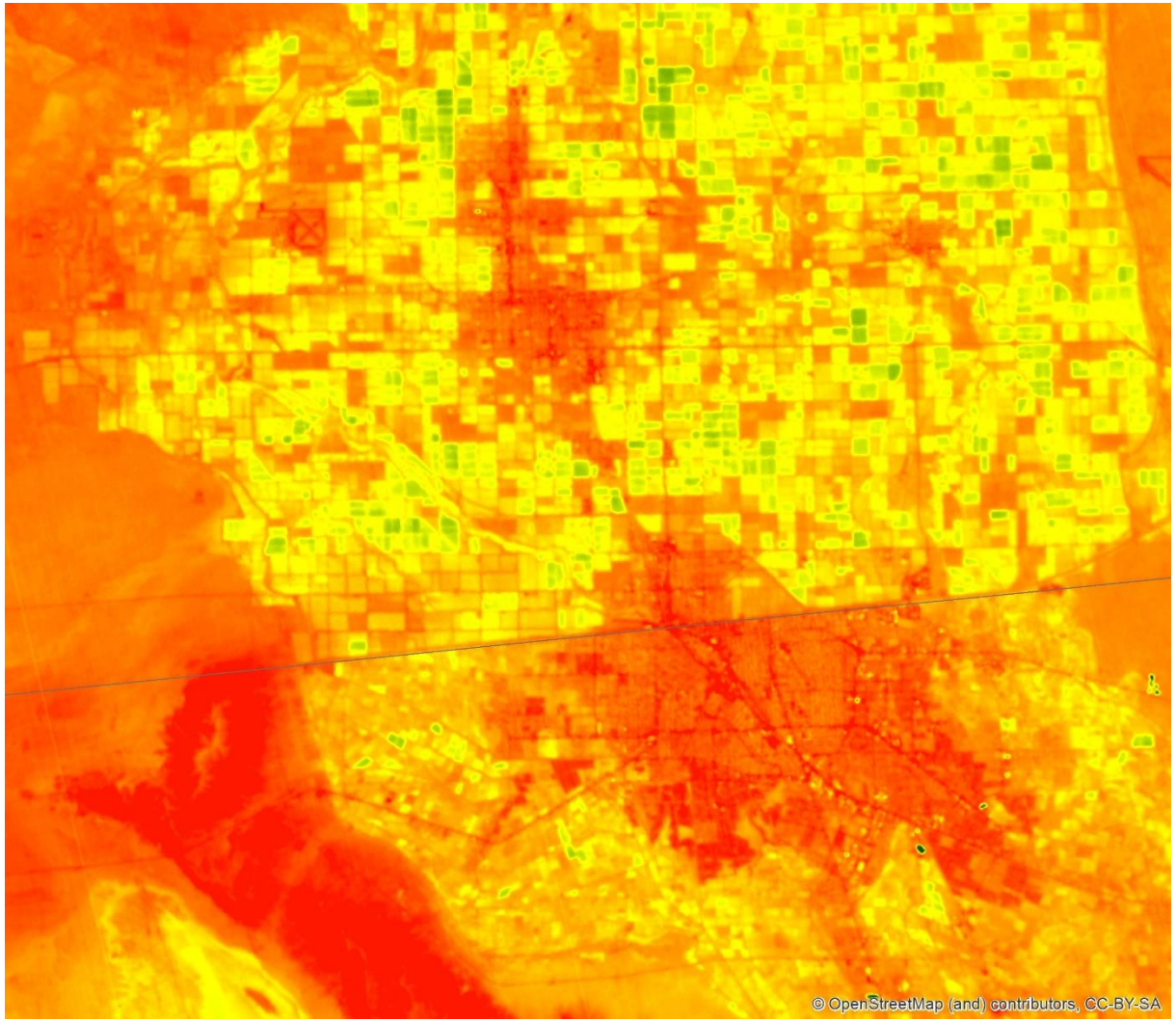
Landsat 8 b10: San Diego/Tijuana (7/16/2019; 5:35 h)

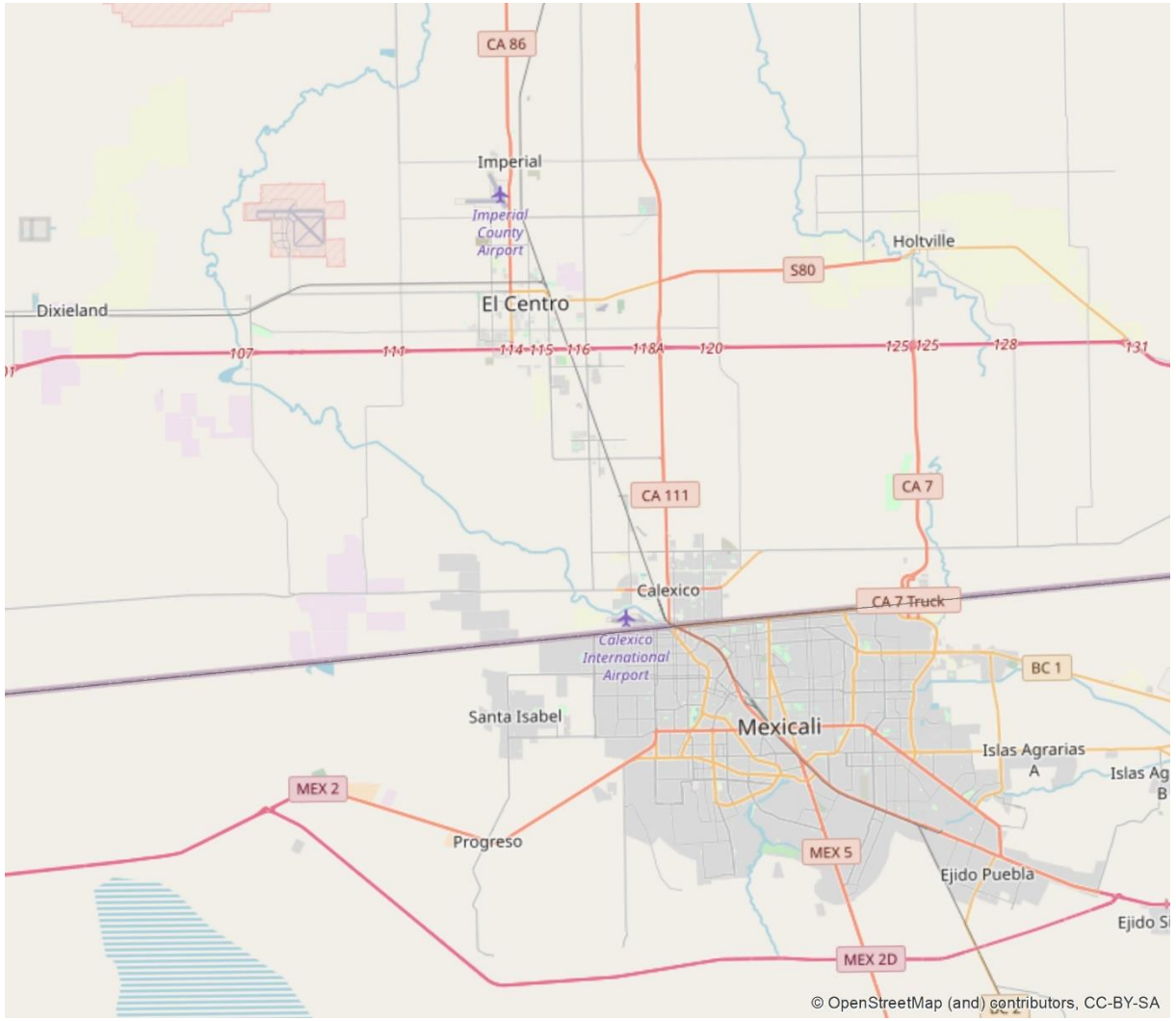




1:250,000

Landsat 8 b10: Mexicali & Imperial Valley (07/16/2019; 5:42h)





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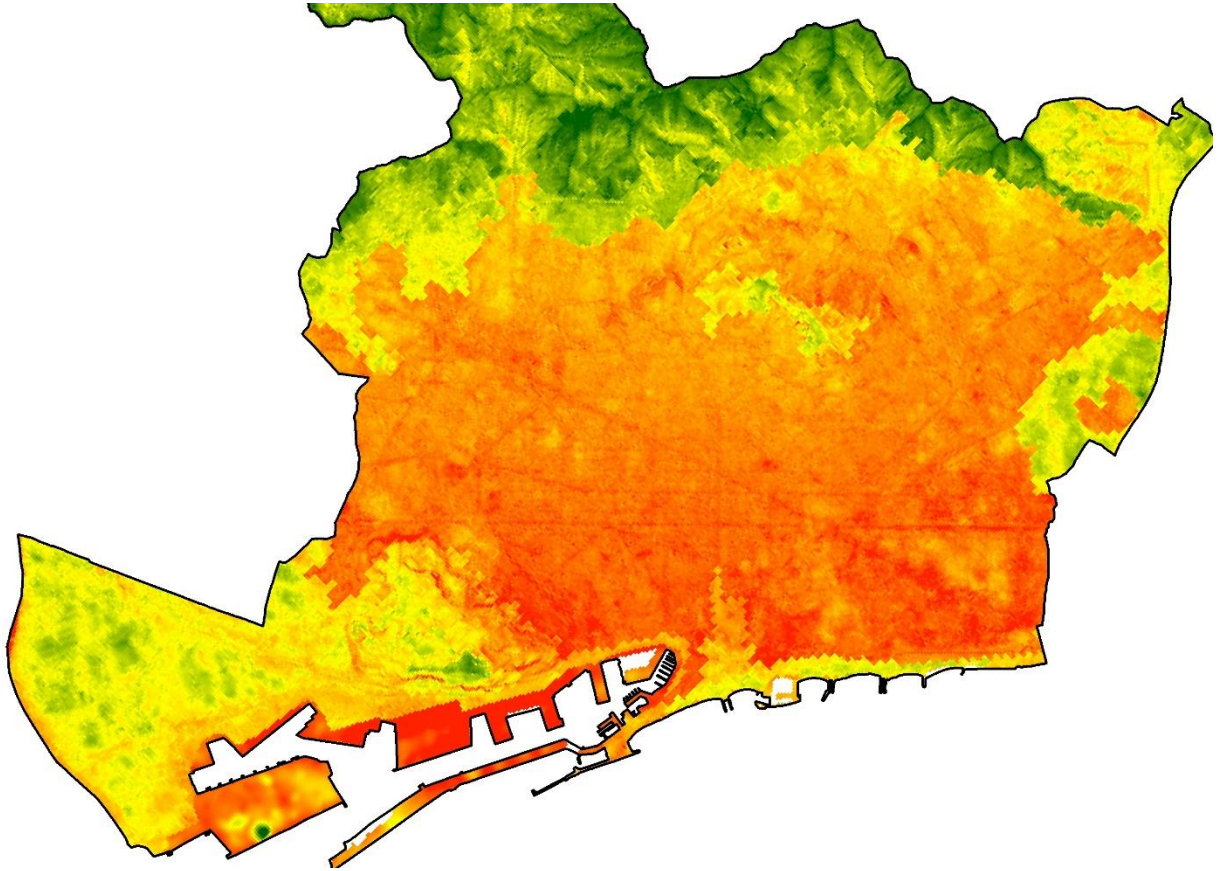
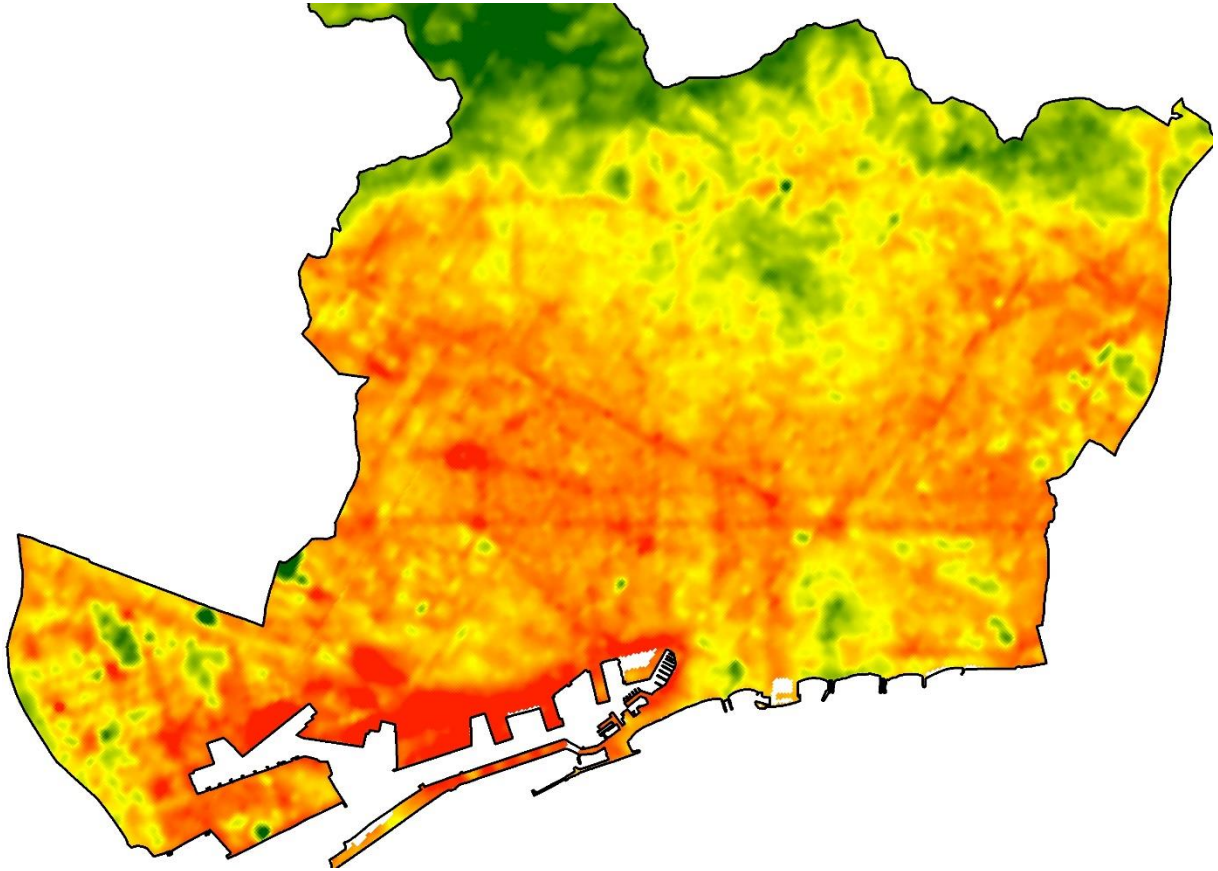
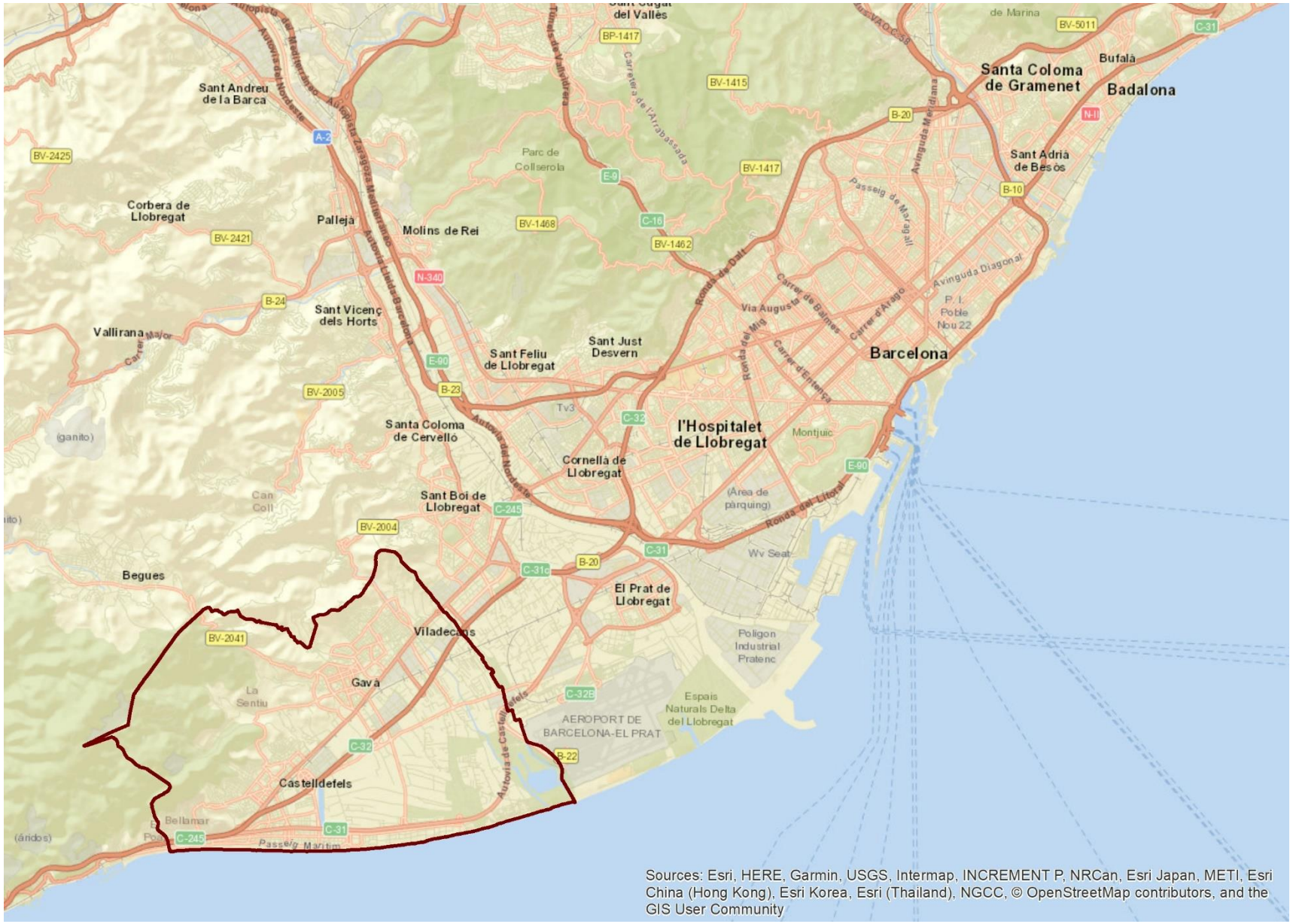
BCN: model MODIS night vs. Landsat night

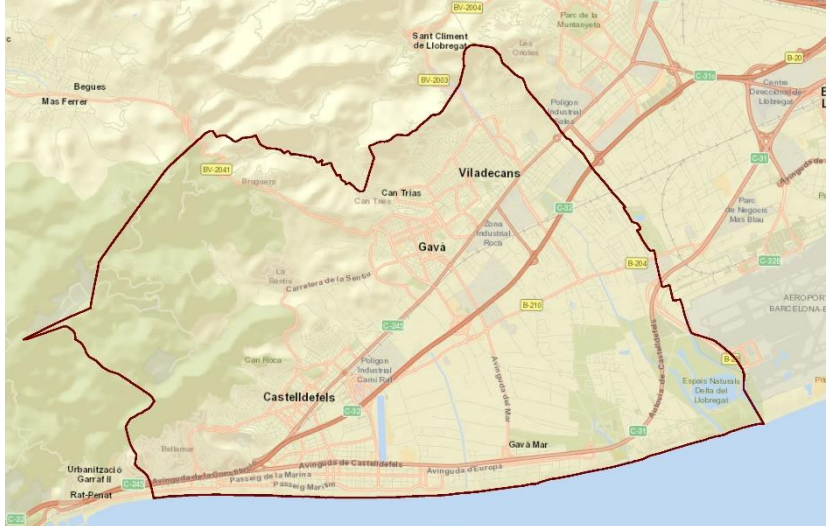




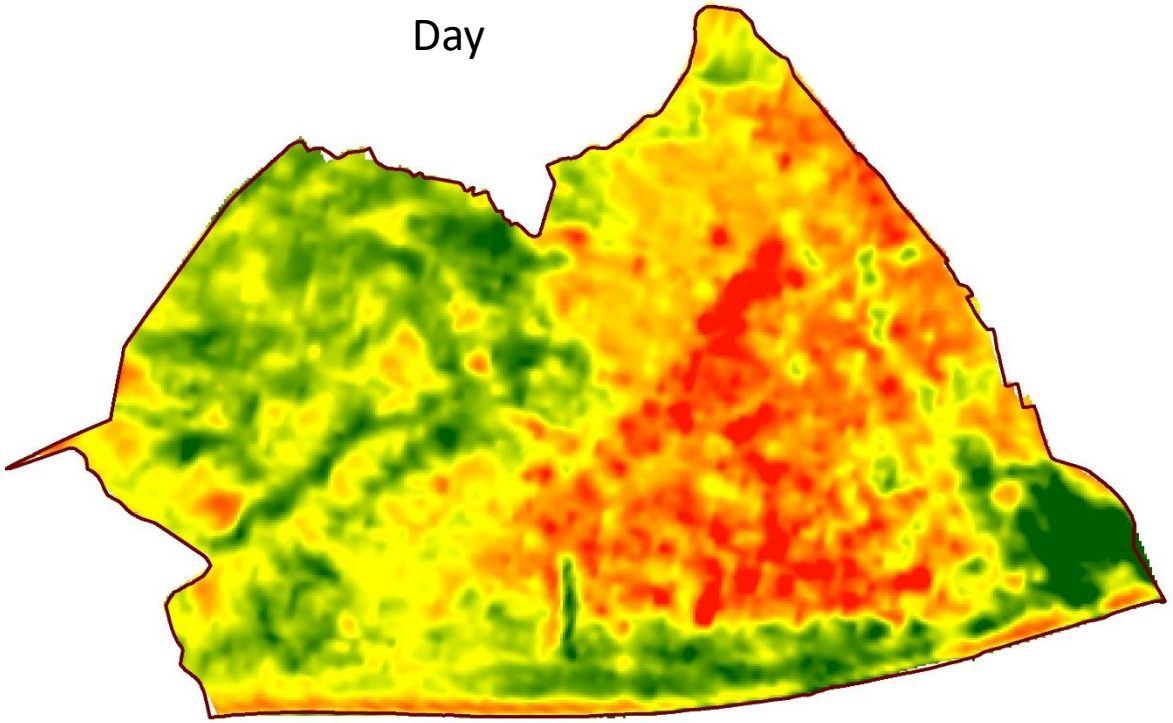
Case study: VGC



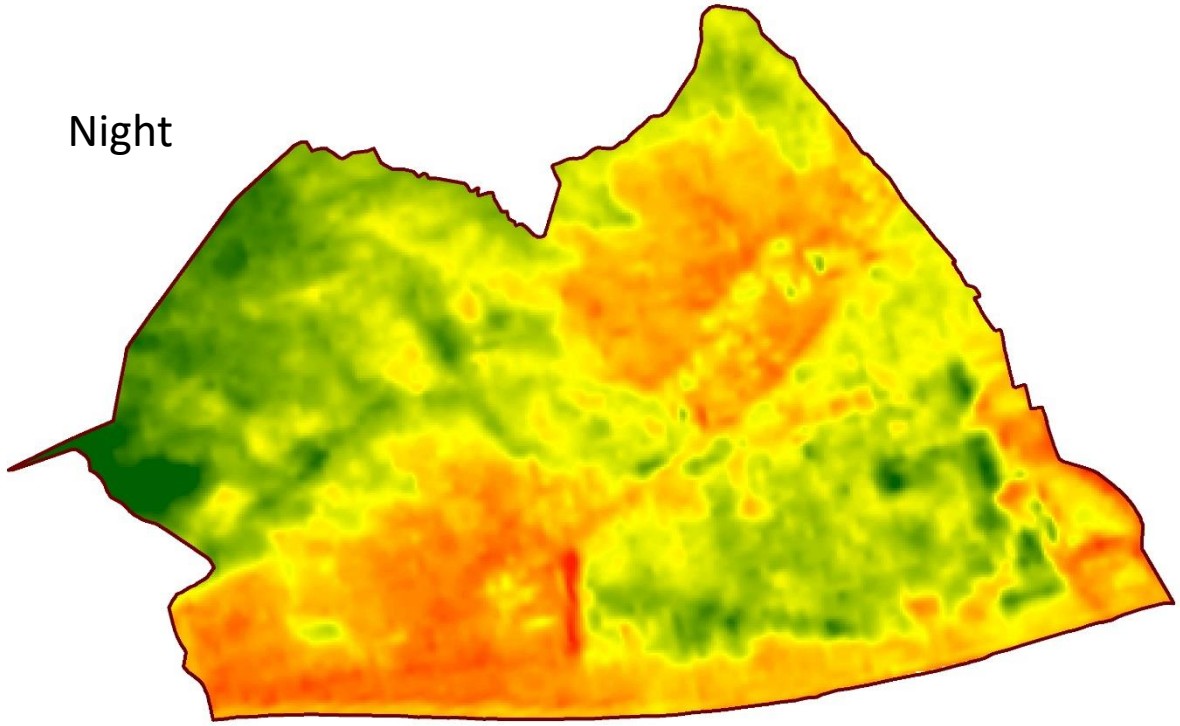
VGC: LST Day vs. Night (Landsat8, august 2018)



Day



Night



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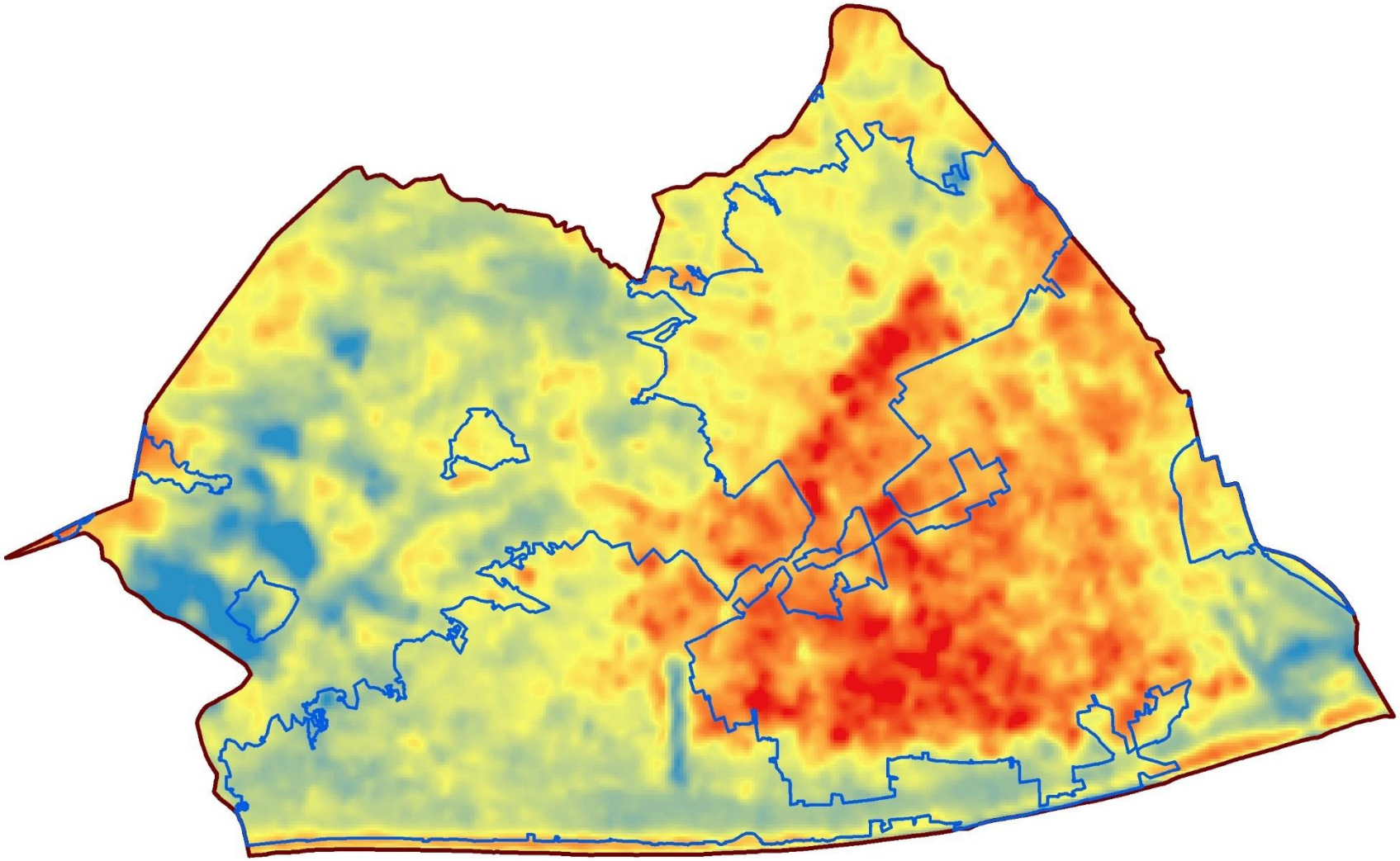
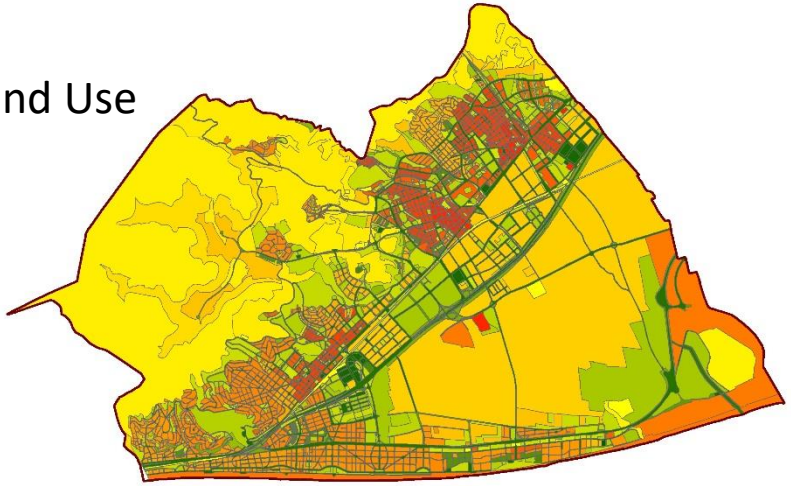
Cooling Day/Night (Landsat8)

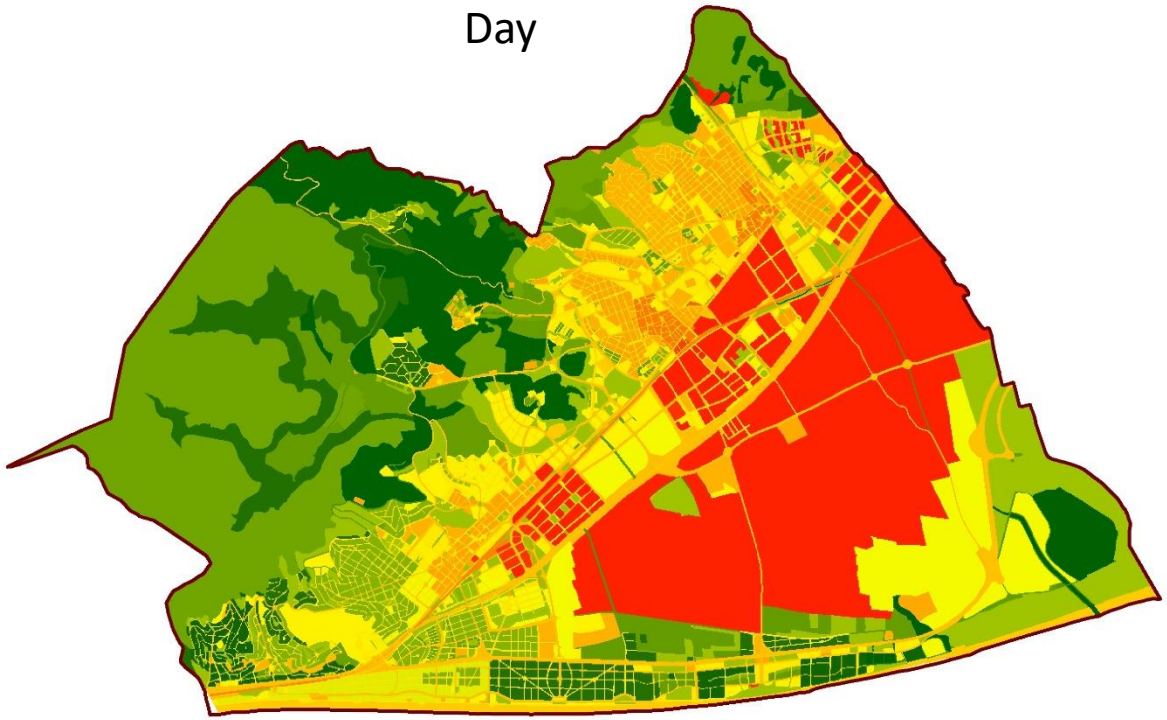


LST Landsat8 day & night by planning

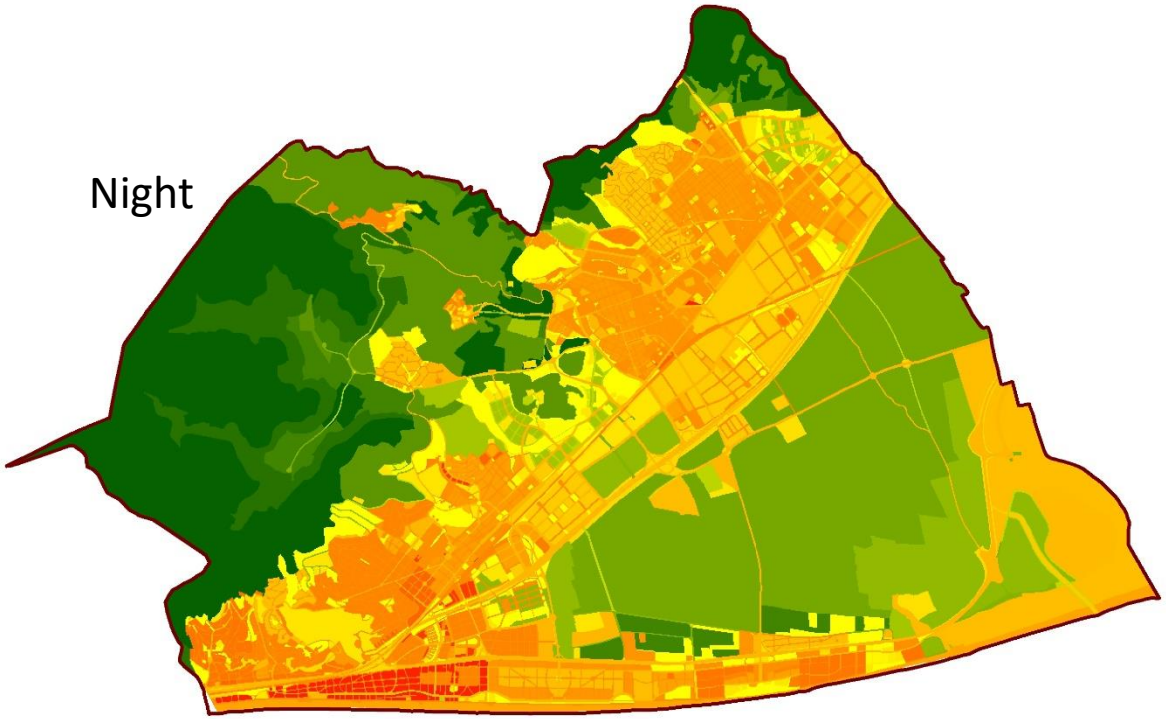
Land Use



Day



Night



Daytime OLS (segmented) model

Resumen del modelo[m]

Art	Modelo	R	R cuadrado	R cuadrado ajustado	Error estándar de la estimación
0	1	,733[a]	,538	,538	688,950
	2	,813[b]	,661	,661	590,076
	3	,819[c]	,672	,672	580,925
	4	,826[d]	,683	,683	570,970
	5	,831[e]	,691	,691	563,747
	6	,836[f]	,699	,699	556,341
	7	,848[g]	,719	,719	537,526
	8	,850[h]	,723	,723	533,540
	9	,851[i]	,725	,725	531,879
	10	,852[j]	,725	,725	531,383
	11	,852[k]	,725	,725	531,181
	12	,852[l]	,725	,725	531,157
1	1	,638[a]	,408	,408	686,481
	2	,752[b]	,565	,565	588,290
	3	,794[n]	,630	,630	542,778
	4	,801[o]	,642	,642	533,864
	5	,805[p]	,648	,648	528,915
	6	,808[q]	,652	,652	526,040
	7	,809[r]	,654	,654	524,676
	8	,809[s]	,655	,655	523,910
	9	,810[t]	,655	,655	523,651
	10	,810[u]	,656	,656	523,377
	11	,810[v]	,656	,656	523,304

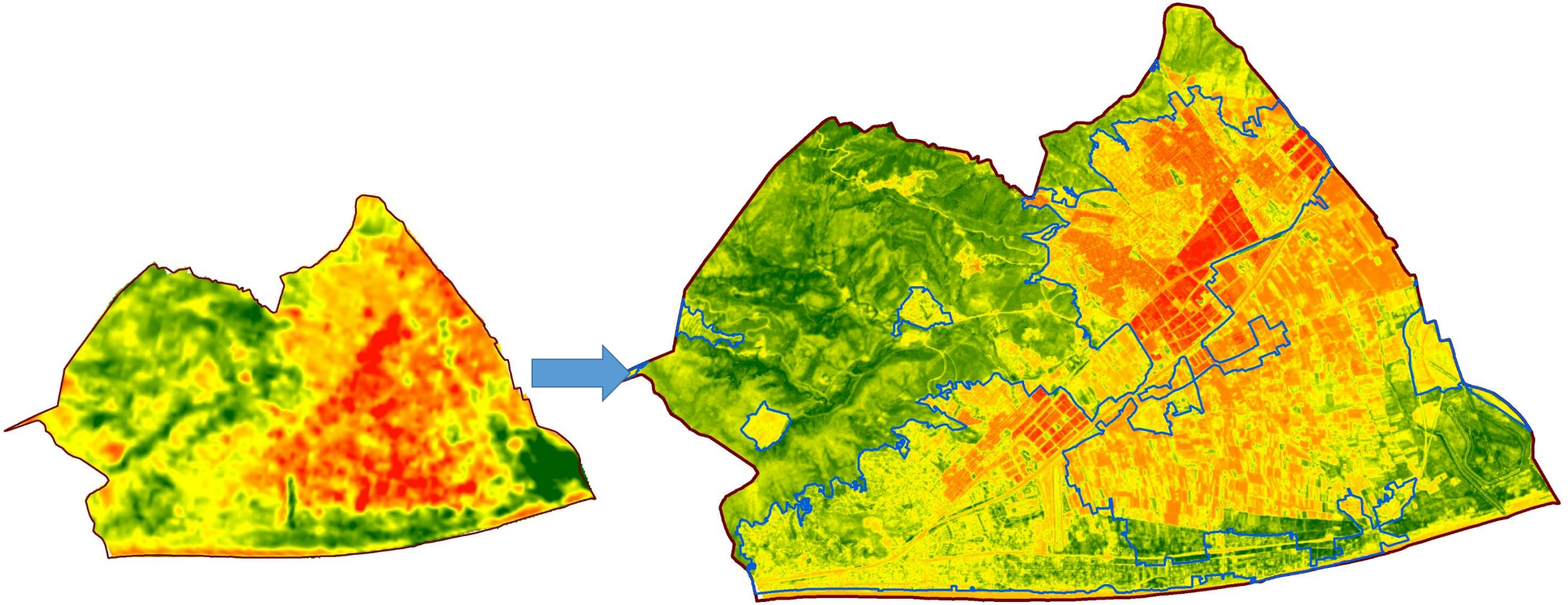
Rural

12	(Constante)	5548451,498	97476,068		56,921	,000
	DN_b10_2018_10m_PGM	,575	,005	,416	111,277	,000
	ndbi_17	1927,925	33,097	,248	58,251	,000
	ndvi_vgc_2018	-1174,780	28,240	-,187	-41,600	,000
	x	,099	,003	,312	32,248	,000
	svf	4,135	,175	,121	23,642	,000
	Dict_Coast	1,251	,021	2,197	59,763	,000
	y	-1,220	,022	-2,027	-56,577	,000
	orient_15m	-,672	,026	-,069	-25,994	,000
	dtm_vgc	,747	,046	,090	16,134	,000
	Dist_Parc	-,268	,029	-,023	-9,083	,000
	solar	5,816E-5	,000	,028	5,864	,000
	Albedo_10m	162,793	73,163	,007	2,225	,026

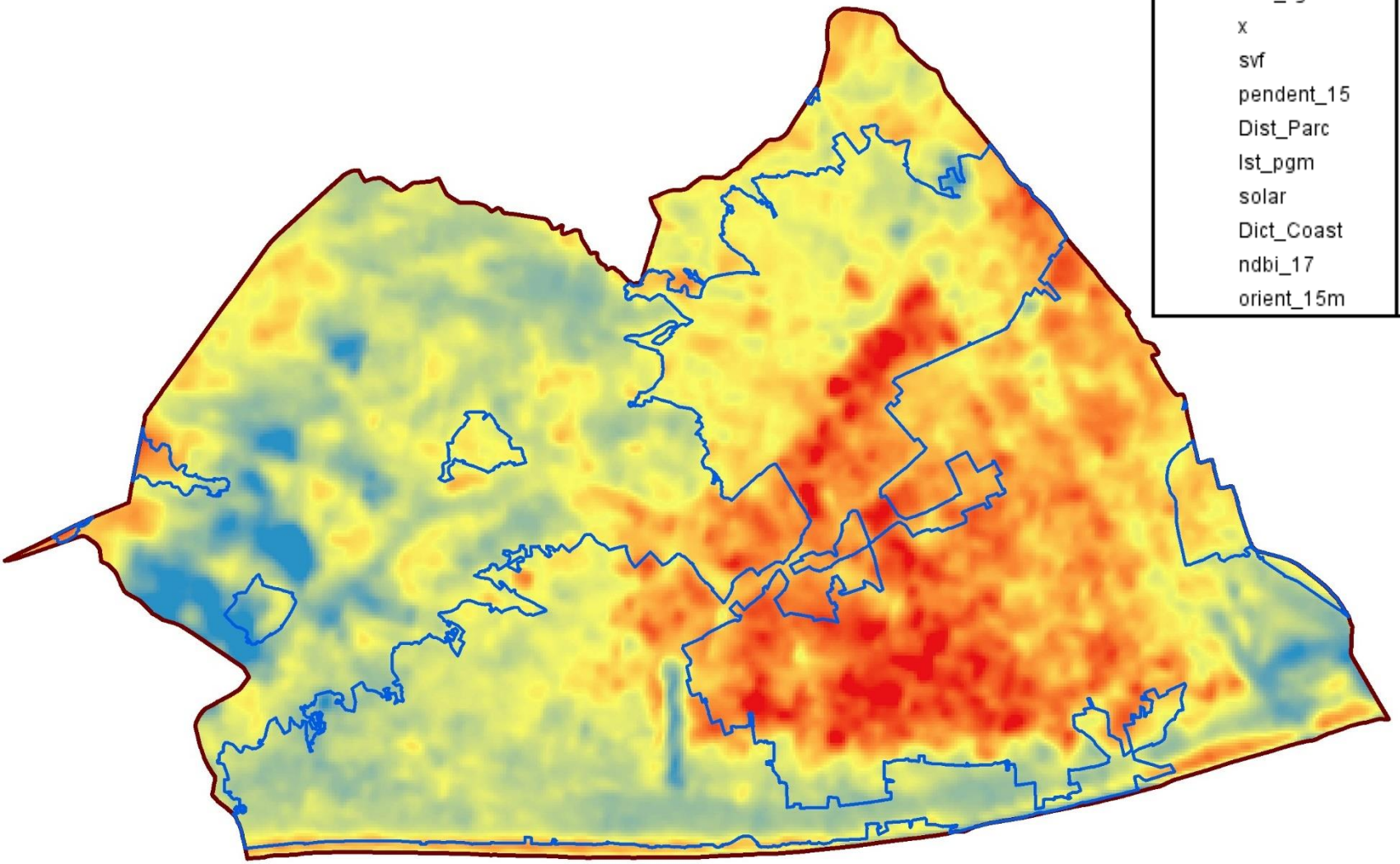
Urbanized

11	(Constante)	-564349,790	10239,063		-55,117	,000
	DN_b10_2018_10m_PGM	,499	,007	,343	74,410	,000
	ndbi_17	1862,488	47,827	,236	38,942	,000
	ndvi_vgc_2018	-618,859	40,555	-,096	-15,260	,000
	x	-,006	,002	-,015	-2,835	,005
	svf	2,541	,224	,080	11,331	,000
	y	,127	,002	,292	53,970	,000
	orient_15m	-,191	,036	-,021	-5,362	,000
	dtm_vgc	,703	,111	,035	6,308	,000
	Dist_Parc	1,407	,086	,073	16,454	,000
	solar	6,718E-5	,000	,036	5,202	,000
	pendent_15	-9,825	,741	-,068	-13,266	,000

Daytime OLS (segmented) model (10m/pixel)



Cooling day/night OLS model

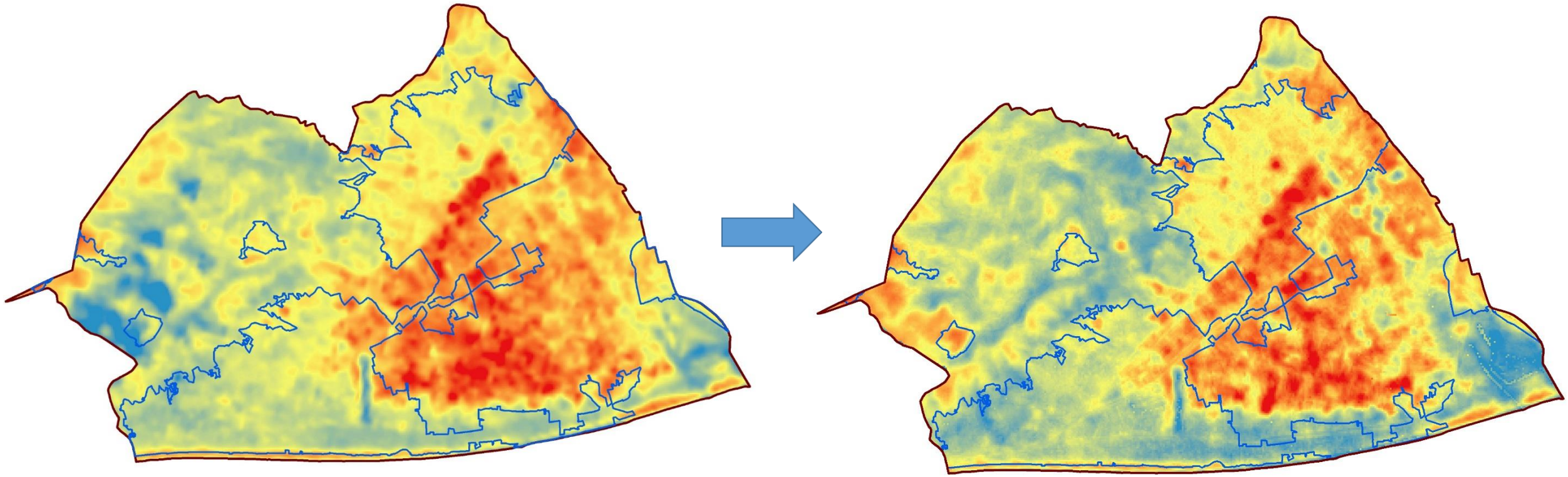


12	(Constante)	-40912,851	201,394		-203,149	,000
	DN_b10_2018	1,078	,001	1,065	739,523	,000
	ndvi_vgc_2018	1220,395	9,183	,212	132,897	,000
	dtm_vgc	2,446	,015	,262	166,167	,000
	x	,027	,000	,079	57,522	,000
	svf	2,260	,058	,067	39,027	,000
	pendent_15	-4,482	,140	-,045	-31,906	,000
	Dist_Parc	,318	,011	,024	28,536	,000
	lst_pgm	18,590	,679	,037	27,396	,000
	solar	-4,516E-5	,000	-,022	-13,577	,000
	Dict_Coast	,005	,001	,010	9,666	,000
	ndbi_17	-79,032	11,707	-,010	-6,751	,000
	orient_15m	-,018	,009	-,002	-2,024	,043

Resumen del modelo

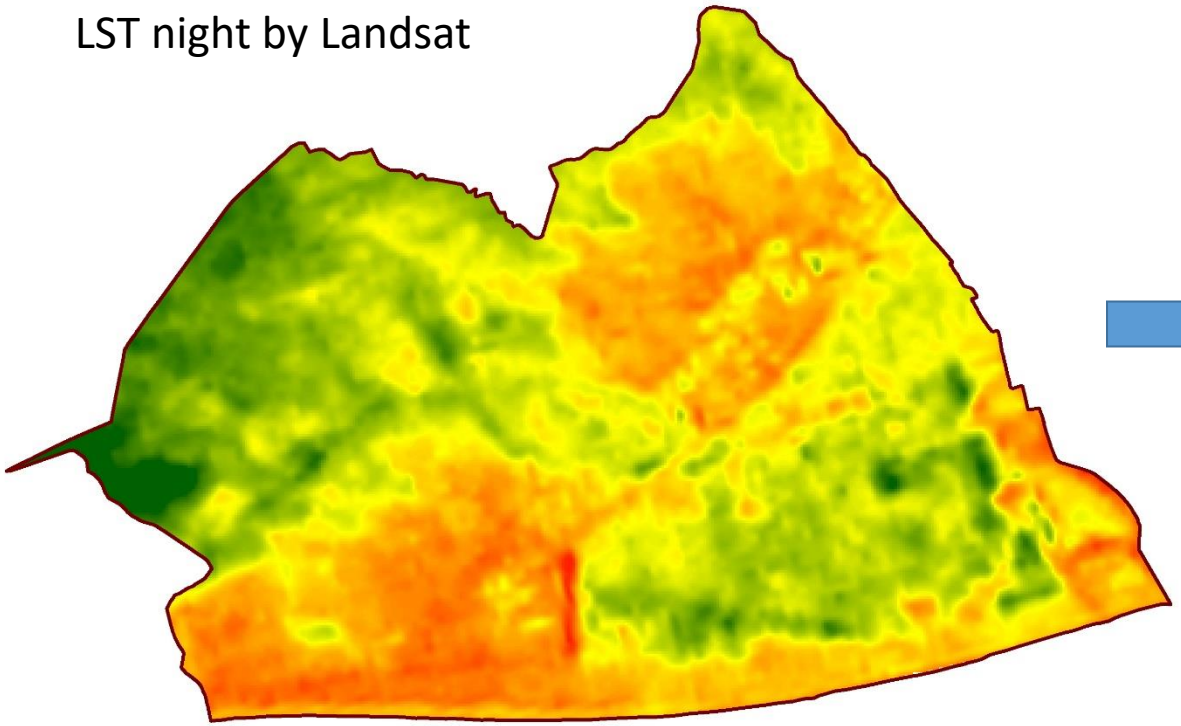
Modelo	R	R cuadrado	R cuadrado ajustado	Error estándar de la estimación
1	,929[a]	,864	,864	368,89924
2	,958[b]	,918	,918	286,25568
3	,969[c]	,939	,939	246,63704
4	,972[d]	,946	,946	233,23126
5	,973[e]	,947	,947	229,19892
6	,974[f]	,948	,948	227,19972
7	,974[g]	,949	,949	225,92064
8	,974[h]	,950	,949	224,68032
9	,974[i]	,950	,950	224,35764
10	,975[j]	,950	,950	224,21129
11	,975[k]	,950	,950	224,13738
12	,975[l]	,950	,950	224,13243

Cooling (Landsat) vs. Cooling OLS model

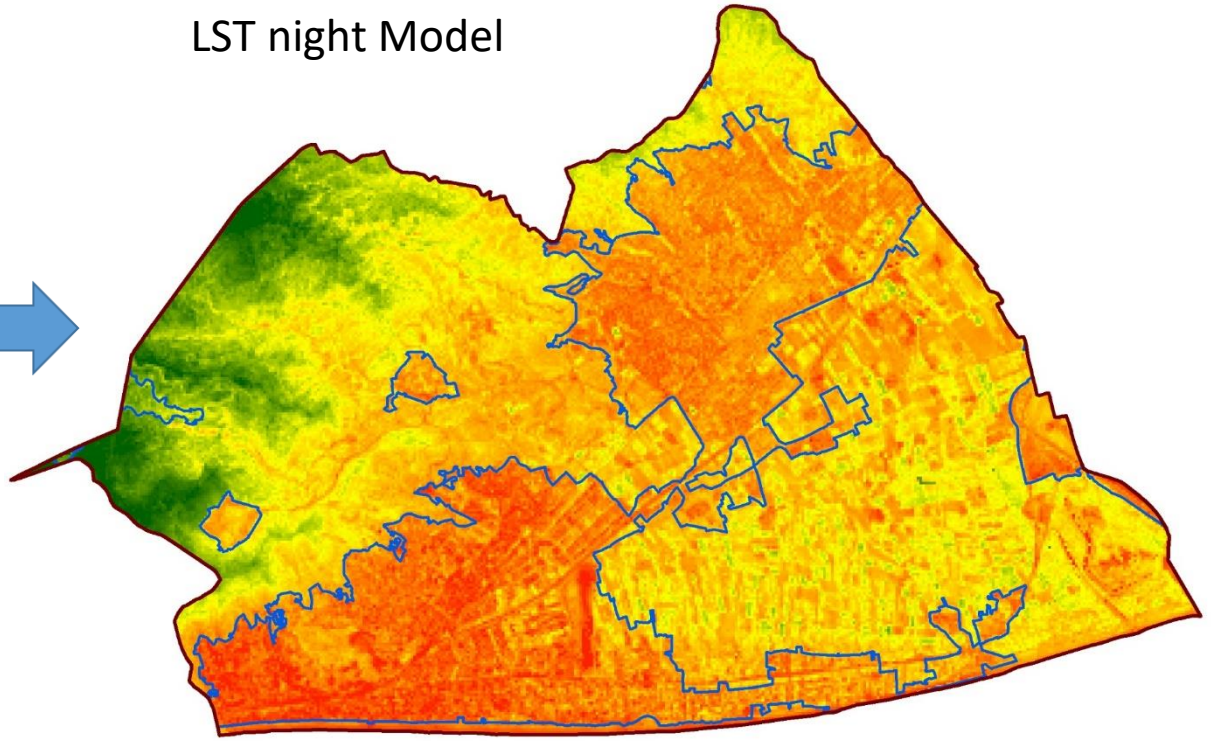


LST nighttime estimated by Cooling Model

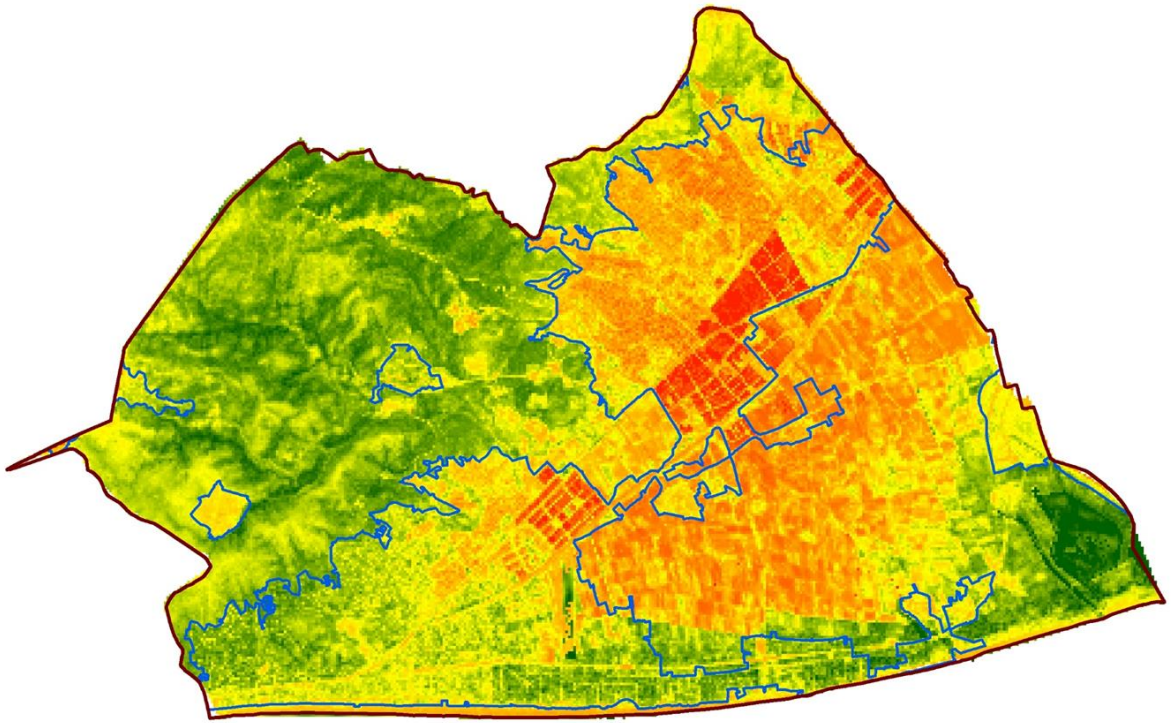
LST night by Landsat

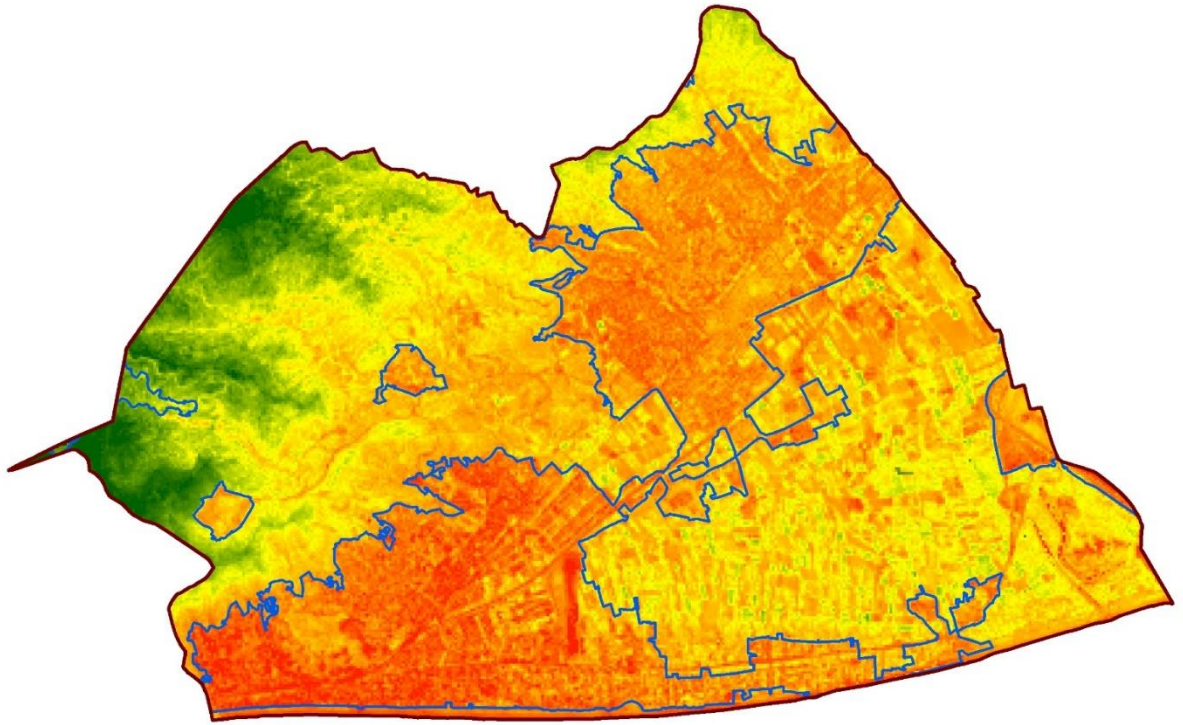


LST night Model



LST daytime and nighttime (10m/p)

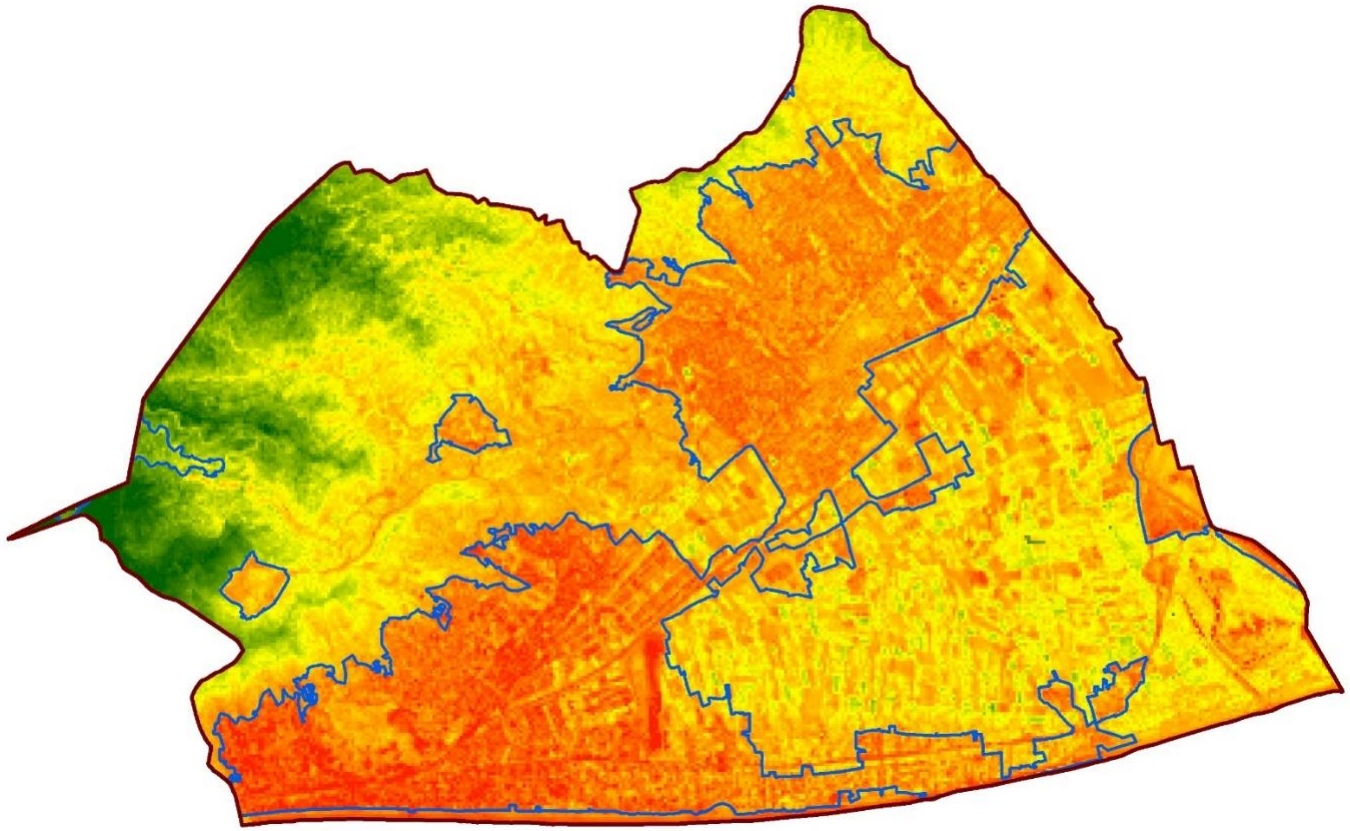




Conclusions

- It is during the night that the effects of UHI become more apparent, due to the low cooling capacity of urban construction materials and is during nighttime that temperatures can cause higher health risks. However, the study of nocturnal UHIs is still poorly developed due to the structural problems regarding the availability of land surface and air temperature data for night time
- The traditional method for obtaining the night UHI has been aimed at extrapolating data provided by meteorological stations, but the lack of such stations in urban landscapes makes it extremely difficult to obtain statistically significant information in order to develop fine-scale models
- Another methodology used to measure nighttime UHI is to use remote sensing, but sensors that provide free information do not generally provide nighttime data (Landsat) or, if they do, they have too low spatial resolution (MODIS)
- Thus, obtaining the nighttime LST is one of the pending research topics on the subject of the UHI
- This paper has been aimed at investigating the information provided by Landsat8 in its very limited series of night images. The results are promising, allowing the develop models which allow to analyze and visualize the UHI at night

Thanks for your attention!



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