

Supplemental materials

A comparison of methods for developing local climate zones to support climate research

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Built types	Definition	Land cover types	Definition
1. Compact high-rise	Dense mix of tall buildings to tens of stories. Few or no trees. Land cover mostly paved. Concrete, steel, stone, and glass construction materials.	A. Dense trees	Heavily wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park.
2. Compact midrise	Dense mix of midrise buildings (3–9 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials.	B. Scattered trees	Lightly wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park.
3. Compact low-rise	Dense mix of low-rise buildings (1–3 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials.	C. Bush, scrub	Open arrangement of bushes, shrubs, and short, woody trees. Land cover mostly pervious (bare soil or sand). Zone function is natural scrubland or agriculture.
4. Open high-rise	Open arrangement of tall buildings to tens of stories. Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials.	D. Low plants	Featureless landscape of grass or herbaceous plants/crops. Few or no trees. Zone function is natural grassland, agriculture, or urban park.
5. Open midrise	Open arrangement of midrise buildings (3–9 stories). Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials.	E. Bare rock or paved	Featureless landscape of rock or paved cover. Few or no trees or plants. Zone function is natural desert (rock) or urban transportation.
6. Open low-rise	Open arrangement of low-rise buildings (1–3 stories). Abundance of pervious land cover (low plants, scattered trees). Wood, brick, stone, tile, and concrete construction materials.	F. Bare soil or sand	Featureless landscape of soil or sand cover. Few or no trees or plants. Zone function is natural desert or agriculture.
7. Lightweight low-rise	Dense mix of single-story buildings. Few or no trees. Land cover mostly hard-packed. Lightweight construction materials (e.g., wood, thatch, corrugated metal).	G. Water	Large, open water bodies such as seas and lakes, or small bodies such as rivers, reservoirs, and lagoons.
8. Large low-rise	Open arrangement of large low-rise buildings (1–3 stories). Few or no trees. Land cover mostly paved. Steel, concrete, metal, and stone construction materials.	VARIABLE LAND COVER PROPERTIES	
9. Sparsely built	Sparse arrangement of small or medium-sized buildings in a natural setting. Abundance of pervious land cover (low plants, scattered trees).	b. bare trees	Leafless deciduous trees (e.g., winter). Increased sky view factor. Reduced albedo.
10. Heavy industry	Low-rise and midrise industrial structures (towers, tanks, stacks). Few or no trees. Land cover mostly paved or hard-packed. Metal, steel, and concrete construction materials.	s. snow cover	Snow cover: >10 cm in depth. Low admittance. High albedo.
		d. dry ground	Parched soil. Low admittance. Large Bowen ratio. Increased albedo.
		w. wet ground	Waterlogged soil. High admittance. Small Bowen ratio. Reduced albedo.

Figure S1, Description of LCZ types.

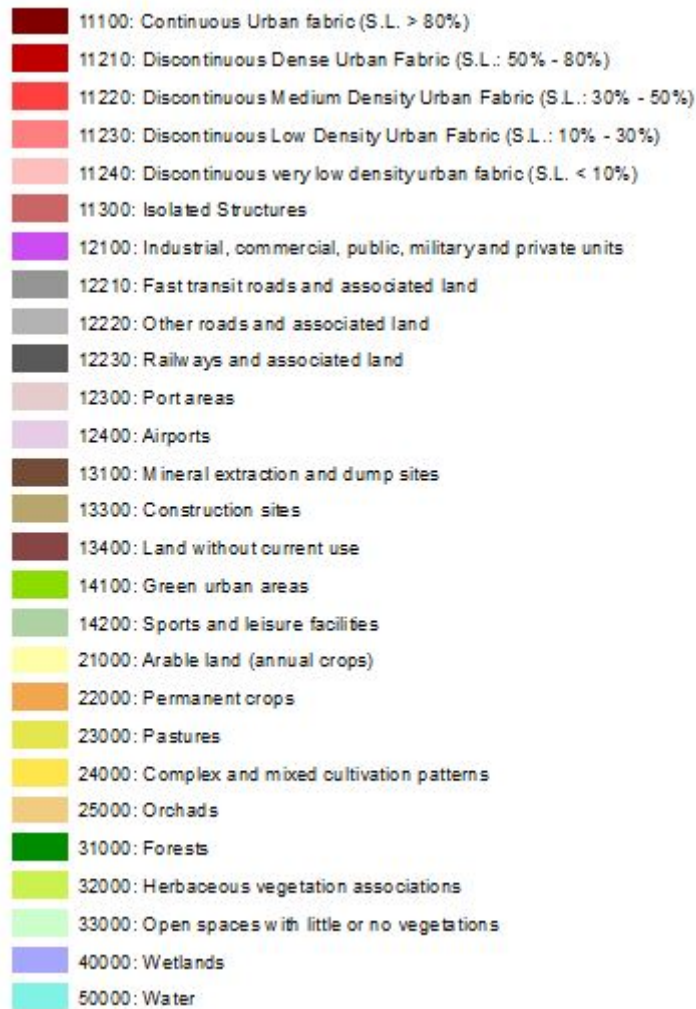


Figure S2, Urban Atlas land use classes

Table S3, Urban Atlas (UA)/Local Climate Zone (LCZ) reclassification matrix

Urban Atlas Type	LCZ Type	UA Code	LCZ Code
Continuous urban fabric	Compact	11100	1, 2 or 3
Discontinuous dense urban fabric	Open	11210	4, 5 or 6
Discontinuous medium density urban fabric	Open	11220	5 or 6
Discontinuous low-density urban fabric	Open	11230	6
Discontinuous very low-density urban fabric	Open	11240	6
Isolated structures	Sparsely built	11300	9
Industrial, commercial, public, military and private units	--	12100	1-6
Fast transit roads and associated land	Bare rock or paved	12210	E (105)
Other roads and associated land		12220	E
Railways and associated land		12230	E
Port areas		12300	E
Airports		12400	E

Mineral extraction and dump sites		13100	E
Construction sites	Not calculated	13300	E
Land without current use	Not calculated	13400	F
Green urban areas	Scattered trees or low plants	14100	B or D
Sports and leisure facilities	Low plants	14200	D
Arable land (annual crops)	Low plants	21000	D
Permanent crops	Low plants	22000	D
Pastures	Low plants	23000	D
Complex and mixed cultivation patterns	Low plants	24000	D
Orchards at the fringe of urban classes	Scattered trees	25000	B
Forest	Dense trees	31000	A (101)
Herbaceous vegetation associations	Scattered trees	32000	B (102)
Open spaces with little or no vegetation	Bush, scrub	33000	C (103)
Wetlands	Scattered trees or low plants	40000	B or D
Water	Water	50000	G (107)
No data (cloud/shadow)		91000	
No data (no image)		92000	

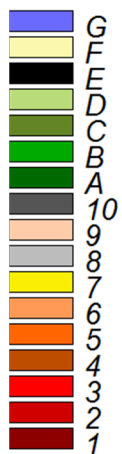


Figure S4, WUDAPT Local Climate Zone (LCZ) color palette and legend

Table S5, WUDAPT validation results – contingency matrix

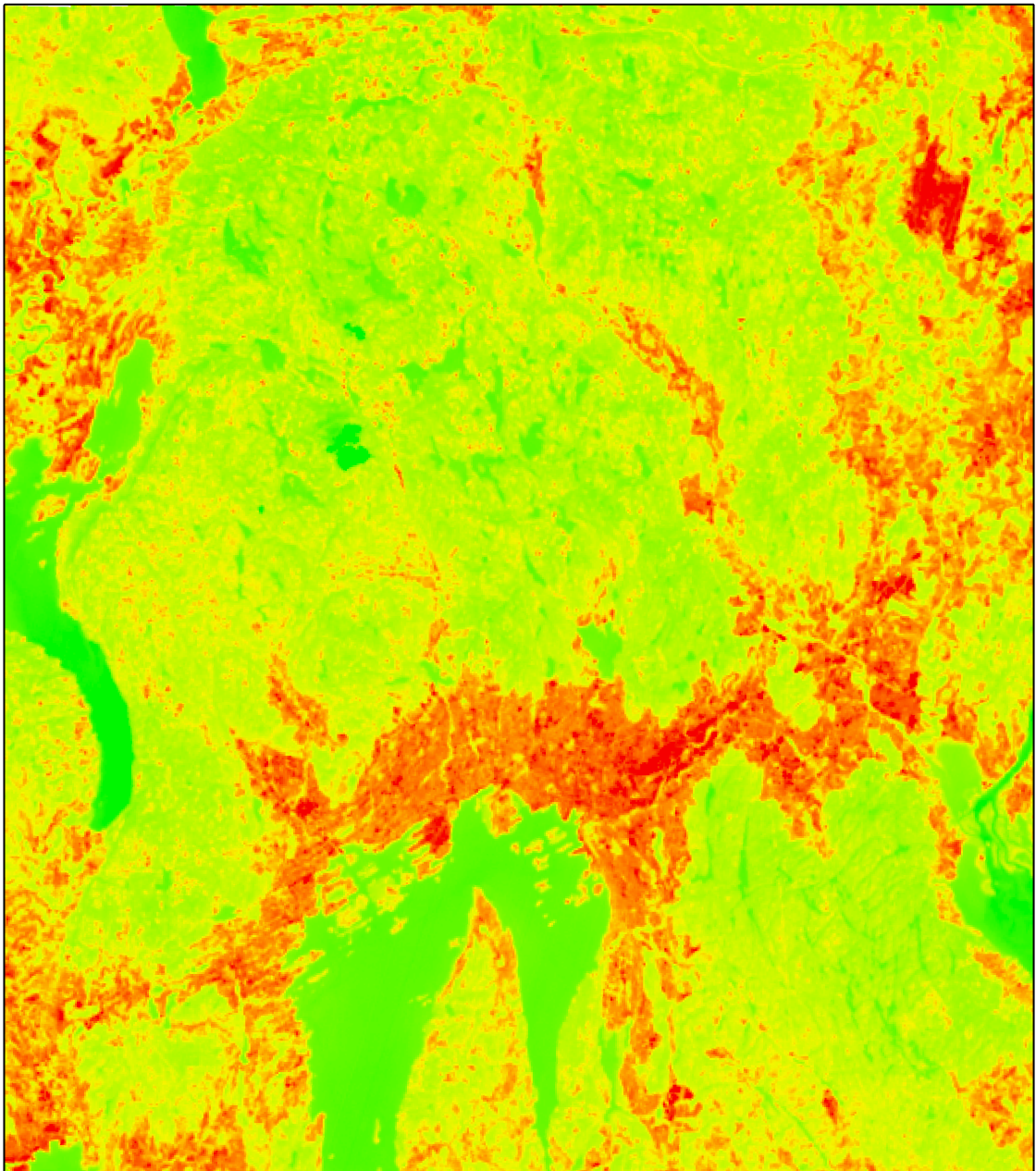
LCZ class	1	2	3	5	6	8	A	B	D	E	F	G	TB	K
1	14												14	1,000
2		130	2			1							133	0,977
3			25	3									28	0,893
5				52									52	1,000
6					164							6	170	0,965
8						165							165	1,000
A							157						157	1,000
B								93	19				112	0,830
D									165				165	1,000
E										95			95	1,000
F											35		35	1,000
G												952	952	1,000
TA	14	130	27	55	164	166	157	93	184	95	35	958	2078	0,46102
Omission	0,000	0,000	0,074	0,055	0,000	0,006	0,000	0,000	0,103	0,000	0,000	0,006		

Table S6, WUDAPT test validation results – contingency matrix

LCZ class	1	2	3	5	6	8	A	B	D	E	F	G	TB	K
1	5					1							6	0,833
2	1	20		1		4				8			34	0,588
3			4	2									6	0,667
5				10	8								18	0,556
6		2		23	46		2	1	4				78	0,590
8		3		1		32				11			47	0,681
A				2			98	1			3		104	0,942
B					3		1	13	5	2	2		26	0,500
D							3	4	27		13		47	0,574
E		1				8				17	1		27	0,630
F				2							8		10	0,800
G												397	397	1,000
TA	6	26	4	41	57	45	104	19	36	38	27	397	800	0,496
Omission	0,833333	0,769	0,000	0,561	0,807	0,711	0,942	0,684	0,750	0,447	0,481	1,000		

Table S7 Google Earth Engine (GEE) method validation results – contingency matrix - %

[illegible]



TIRS Landsat 8 Oslo 30/7/2018

Temperature variation C

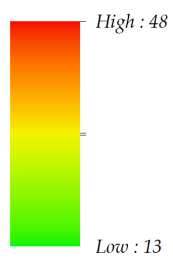


Figure S8. Landsat 8 TIRS image (colorscale applied), 30/7/2018 - Oslo area

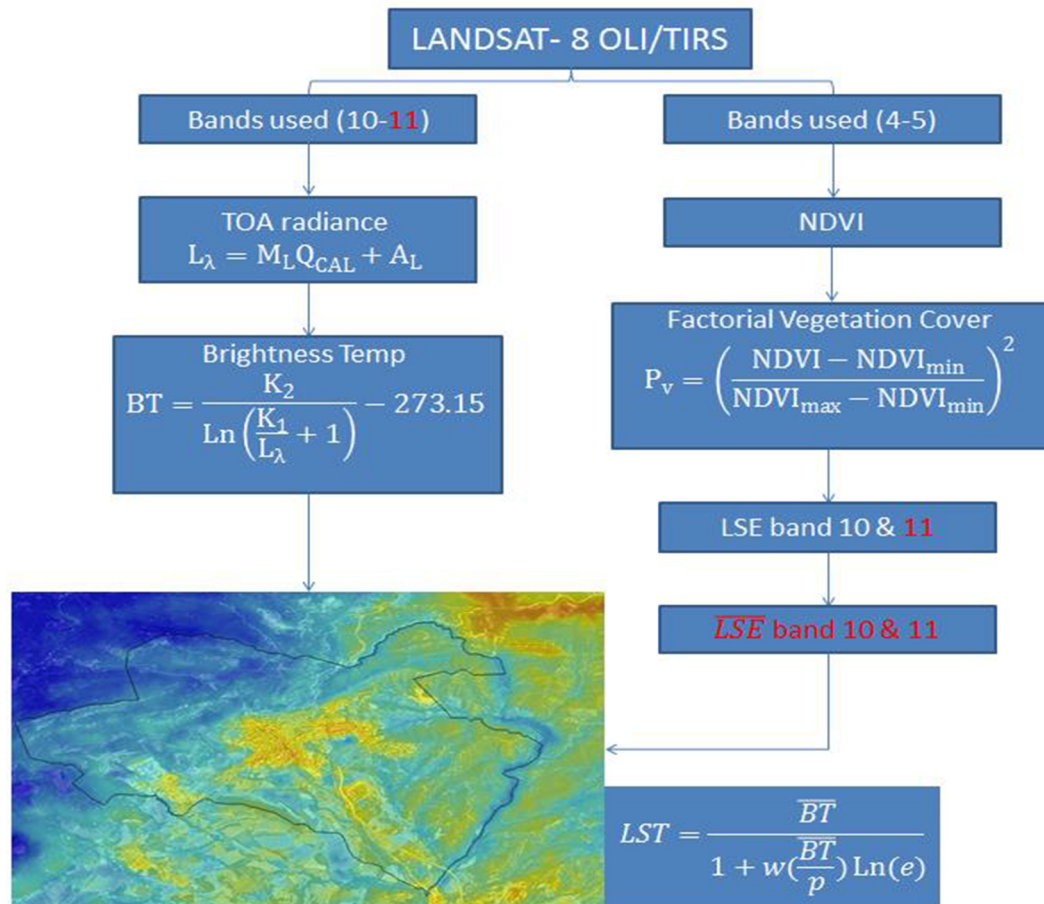


Figure S9. USGS LST raster generation workflow

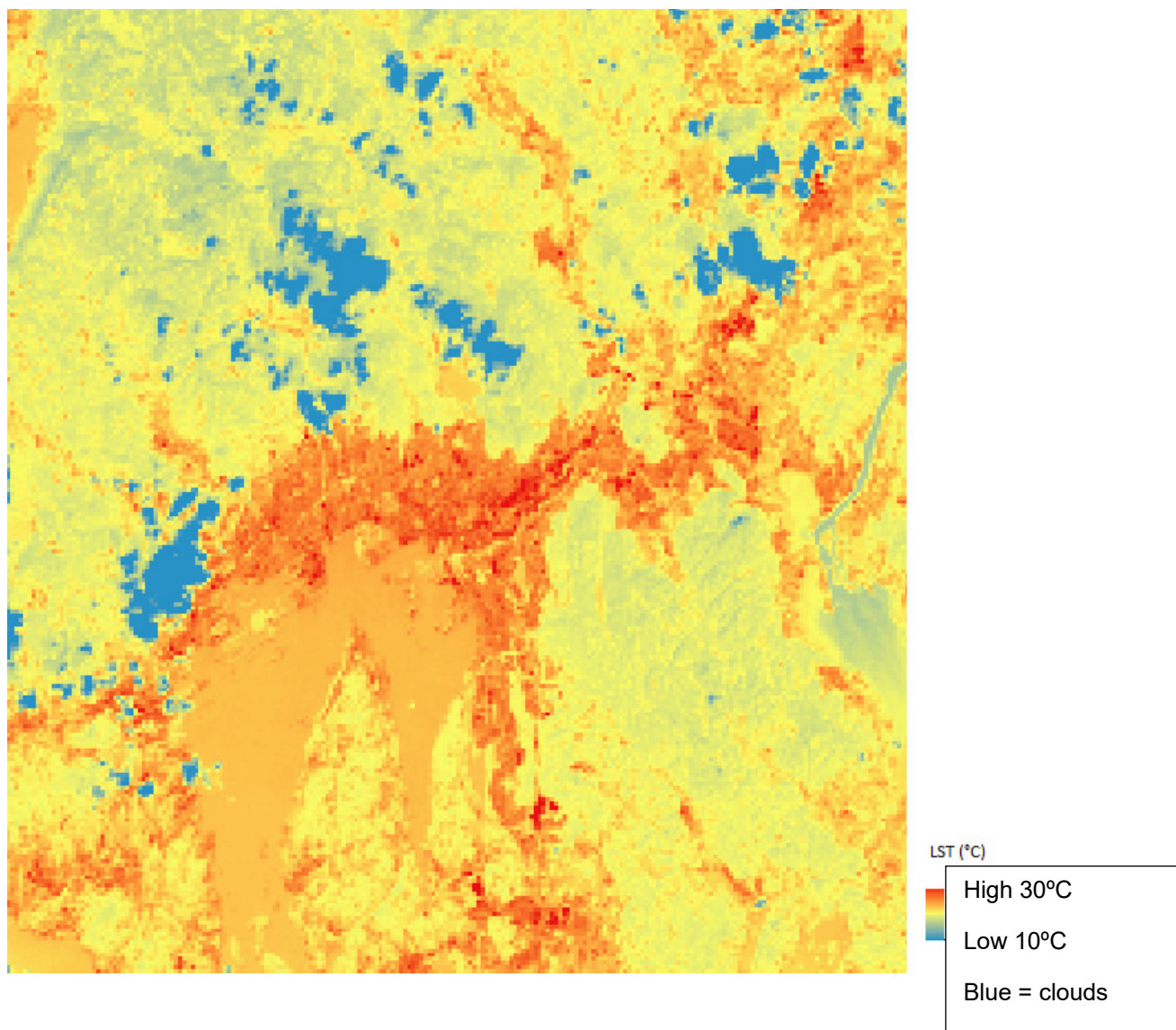


Figure S10. Landsat 8 TIRS image (colorscale applied), 25-08-2020- Oslo area

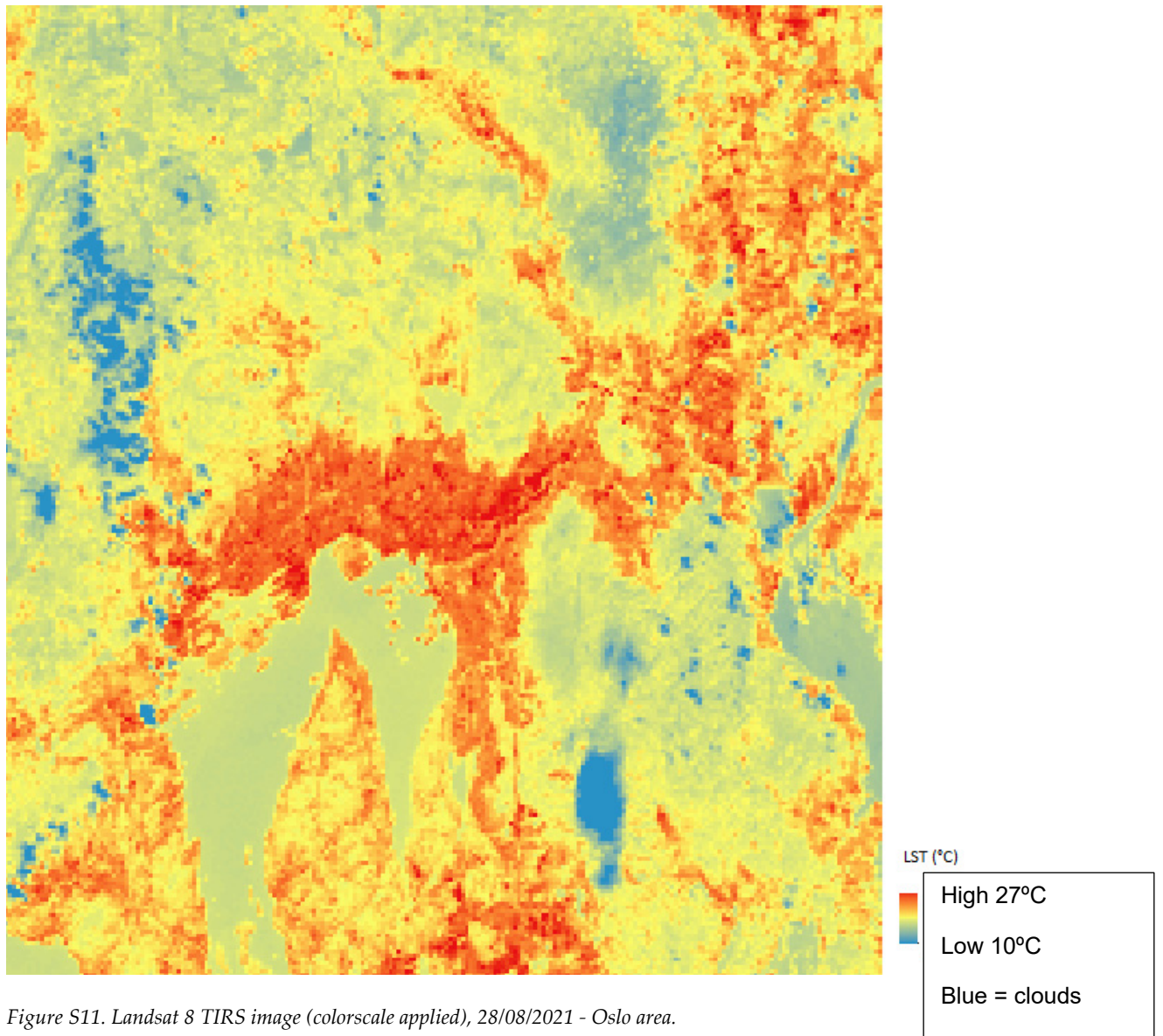


Figure S11. Landsat 8 TIRS image (colorscale applied), 28/08/2021 - Oslo area.

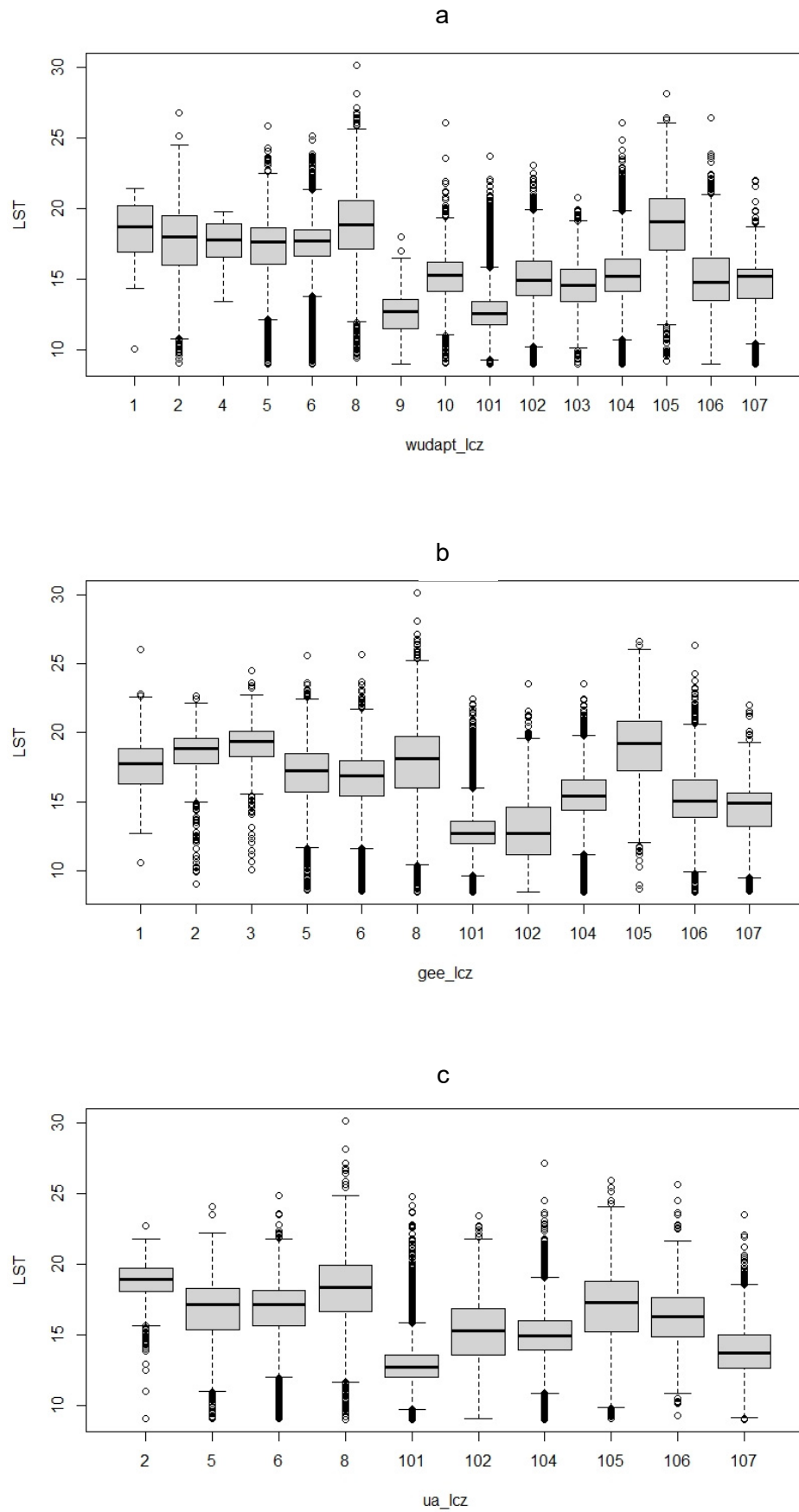


Figure S12 a/b/c. LCZ temperature distribution for 25th August 2020, WUDAPT method (a), GEE method (b), UA method (c).

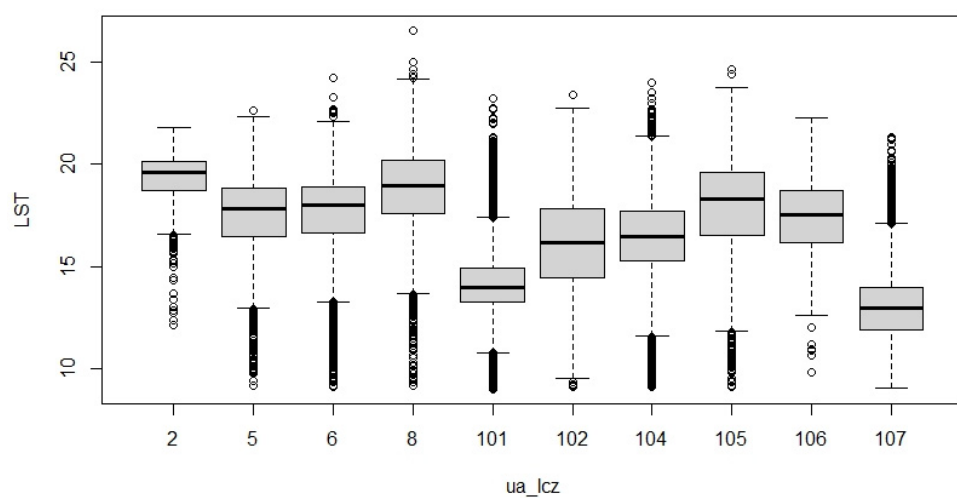
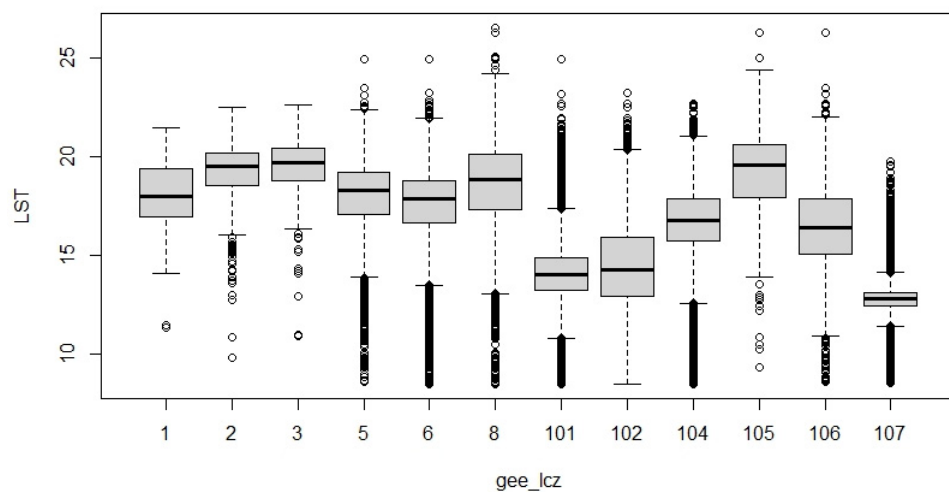
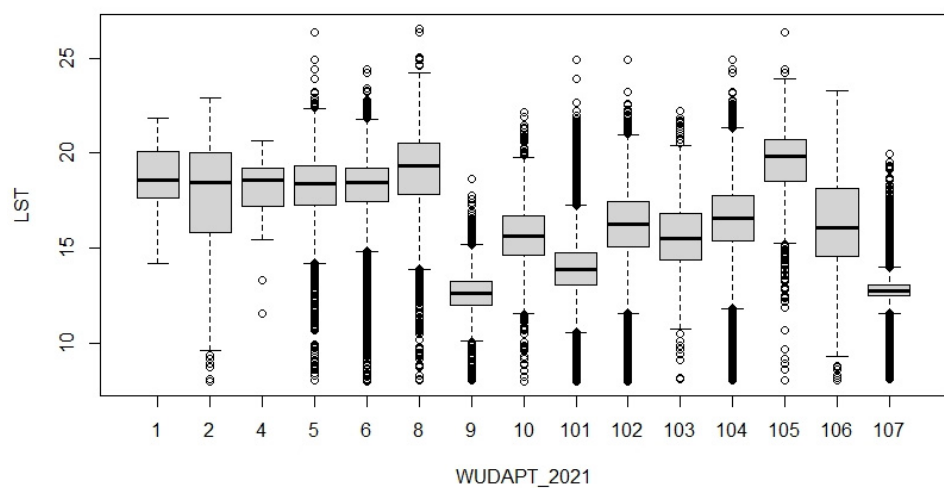


Figure S13 a/b/c. LCZ temperature distribution for 28th August 2021, WUDAPT method (a), GEE method (b), UA method (c).

Table S14. A summary of the differences amongst the three methods to generate LCZ.

	WUDAPT	GEE	GIS/UA
Relative ease of creation of LCZs by method	Requires knowledge of image processing, machine learning, and GIS geoprocessing	Requires knowledge of GEE and machine learning, albeit contained in online software suite	Requires basic knowledge of scripting and GIS client operation
Accuracy of results	High: Kappa > .98	High: Kappa > .97	Variable: dependent on source vector data
Specialized software required to be owned	Yes: Google Earth, SAGA, USGS Explorer,	No	Yes: a GIS client
Target audience	GIS professionals, climatologists, engineers, academics	GIS professionals, climatologists, engineers, academics, public government staff	Any
Resolution	100m2 (Landsat 8)	100m2 (Landsat 8)	Any
Discrepancies	LCZ zones 1-3, A-B, 8-E	LCZ zones 1-3, A-B, 8-E	Any: land uses can encompass any LCZ
Pros	Highly accurate and machine learning can be retrained and adjusted for optimal results. Uses maximum satellite bandwidth.	Highly accurate, can be performed all online in one place. Follows the same ML based workflow as WUDAPT.	Easy to learn and use, can generate LCZs extremely quickly. Can be higher resolution than satellite imagery.
Cons	Extremely lengthy process, high learning curve until technique is mastered. Many moving parts and inputs. Requires specific software.	High learning curve, limited options compared to WUDAPT, dependent on one provider. Less 'tweakable' than WUDAPT.	Wholly dependent on quality and validation of source vector data. Tends to 'bunch' LCZs in categories.