Titolo della tesi

Monitoring Urban Heat Island through Google Earth Engine at large scale: potentialities and diffculties in the case of different cities in the United States

(specificare se sperimentale, progettuale o compilativa)

……Sperimentale……

Tipo di Laurea (triennale, magistrale con indirizzo)

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Riassunto della tesi (max 2 pagine)

Il riassunto della tesi non deve superare le due pagine e non devono essere inserite figure

The Urban Heat Island (UHI) and the Global Warming increase ambient temperature and modify the energy budget of buildings. The UHI depends on many parameters, such as : the soil moisture, the topographic characteristics of the city, the weather conditions, the urban density, the anthropogenic heat released, the thermal and radiative characteristics of the used materials in the city fabric, the urban form and land use. In parallel, urban warming is associated to the increase of the concentration of urban pollutants, in particular of the tropospheric ozone, worsens thermal comfort conditions in outdoor spaces and increase health and mortality problems and the urban ecological footprint. The increase of the temperature has serious consequences on the energy, environmental and social balance of cities. The most serious impact is associated to the significant increase of the peak and total electricity demand especially for cooling purposes.
It was well documented that with the rapid urbanization and population growth, increasing in built-up land and replacing of nature lands with artificial buildings altered surface energy budgets, the hydrological cycle, and could effect local, regional and global climate by changing the surface physical properties. Thus, understanding the role of urban land-use and its impact on the climate system is of interest in the context of global warming.

In particular, the term UHI refers to the phenomenon of higher atmospheric and surface temperatures occurring in urban areas than in the surrounding rural areas due to urbanization. It is characterized by a large expanse of non-evaporating impervious materials covering a majority of urban areas with a consequent increase in sensible heat
flux at the expense of latent heat ux. UHI effects are exacerbated by the anthropogenic heat generated by traffic, industry and domestic buildings, impacting the local climate through the city's compact mass of buildings that affects exchange of energy and levels of conductivity. The magnitude and pattern of UHI effects have been major concerns of many urban climatology studies.

The aim of this work is to leverage the global-scale analysis capabilities of Google Earth Engine (GEE) to study the temporal variations of the Urban Heat Island (UHI) effect at "large scale". GEE is indeed the computing platform recently released by Google "for petabyte-scale scienti_c analysis and visualization of geospatial datasets". Using a dedicated HPC (High Performance Computing) infrastructure, it enables researchers to easily and quickly access more than thirty years of free and public data archives, including historical imagery and scienti_c datasets, for global and large scale remote sensing applications. In this way, many of the limitations related to the data downloading, storage and processing, that usually occur when a such large amount of information (Big Data) is analyzed, are effortlessly overcome.

Specifically, the work was focused on five different USA Metropolitan Areas (USA MAs), characterized by different climate conditions: Atlanta, Boston, Chicago, Houston and San Francisco. In the last decades, the investigated USA MAs were indeed subjected to a significant urban expansion which has profoundly modified the character and state of their territories. Residential suburbs, commercial and industrial areas have replaced the forests and/or agricultural hinterlands surrounding the traditional downtown urban centers: soils that were once permeable and wet were transformed in waterproof and dry surfaces.

The analysis was conducted as follows.

The Climate Engine Application, powered by GEE, was used to compute the annual mean of the Land Surface Temperature (LST) from Landsat Top of Atmosphere Reectance Data for every year of the temporal range comprised between the 1992 and the 2011 on the Regions Of Interest (ROI) corresponding to the five different USA MAs. The USGS National Land Cover Database (NCD) was directly retrieved from GEE for the same temporal range and ROIs. For each USA MAs, at a first stage, a pixel-wise analysis was performed through dedicated scripts developed in Python; for every pixel of each ROI, the parameters of a simple linear model describing the LST trend as a function of time were robustly estimated. Overall, a positive trend for LST was retrieved. Generally, for every city, the LST presents a positive trend, probably due to the effects of the global warming, but with rates variable within the ROI . Therefore, a spatial analysis was performed to identify areas with homogeneous LU variations in order to cluster pixels with similar behavior, namely the same temperature trend, and to investigate their relationship with the most significant urban expansions areas. Operatively, two matrices were computed, following the linear temperature growth model, one for the constants (T at the initial year) and one for the slopes, in which every cell ij aggregates all the pixels of the ROI with a specific Land Use (LU) i in the initial year (1992) and with a specific LU j at the final year (2011). Moreover, every cell stores the statistical parameters computed considering the values of T at 1992 (constant matrix) or of slope (slope matrix) of all the ROI pixels subjected to the LU change from i to j. Analyzing the results, the general increasing trend of the LST is evident in the principal diagonal of the slope matrix (the ROI pixels that were not subjected to a LU change during the time period analyzed) practically for every city. Furthermore, the LST increases with a higher rate when the change of LU from cultivated or forest to urbanized occurs. Finally, when the pixels change from urbanized to forest, the LST increase is smaller.

Moreover, an analysis was carried out to understand if the increase in temperature was due only to the UHI or if there were other causes, such as the Global Warming. In the first case it is about local changes due to the change in land use, in the second case it is the increase of greenhouse gases in the atmosphere.

In conclusion, the analysis of the five USA MAs performed in this thesis clearly shows how urbanization heavily influences the UHI magnitude with significant increases in LST. It is difficult to quantify how much urbanization and climate change each contribute to todays urban heat islands in the U.S., because each city has a unique and constantly- changing urban landscape and because climate change is regionally sensitive. Yet, it is clear that the combination of continued urbanization and climate change is going to make cities even hotter.

Lastly, the obtained results demonstrate the effectiveness of the developed methodology for studying the temporal variations of the UHI phenomenon at large-scale in an efficient way, thanks to the processing capabilities of GEE, and allow to provide possible predictions for future trends, thus giving valuable indications to address the urban
planning of the city. In addition, a future perspective is certainly to extend the analysis to other urban areas (even outside the USA) and to extend this methodology using Sentinel-2 and Sentinel-3 data (SEN4LST project) as well.