**The Urban Bundle Protocol**

**I. Introduction**

The urban environment is a reflection of urban dynamics, including the surface and atmosphere energy balance, the transfer of air masses and the resulting dispersion of air pollutants and the energy and heat fluxes in between the surface and the atmosphere close to the surface. It consists of non-homogeneous areas in terms of urban density, population density, land use/cover, greenery and cooling sinks, the intensity and spatial dispersion of anthropogenic heating sources, rain run-off features, and more.

In recent years, the urban environment is not simply considered as an agglomeration of buildings, but rather as a ‘living organism” that constantly changes mostly due to anthropogenic causes. Given this perspective, it is important to: (a) take note of individual and nested systems from the natural environment, the built environment and the socio-economic environment and (b) to define the physical, chemical and environmental processes, including their interactions, which influence and/or control the urban environment.

The purpose of the **Urban Bundle** is to suggest a group of GLOBE protocols that can provide students and teachers with integrated knowledge of the environment in urban areas, including various processes and their interactions. Given the many small-scale variations caused by the built environment, such citizen science contributions are particularly needed to adequately characterize the urban environment.

Figure 1 provides a graph of the Urban Bundle; the main thematic categories to be studied are provided in the middle of the graph and are linked to GLOBE protocols.

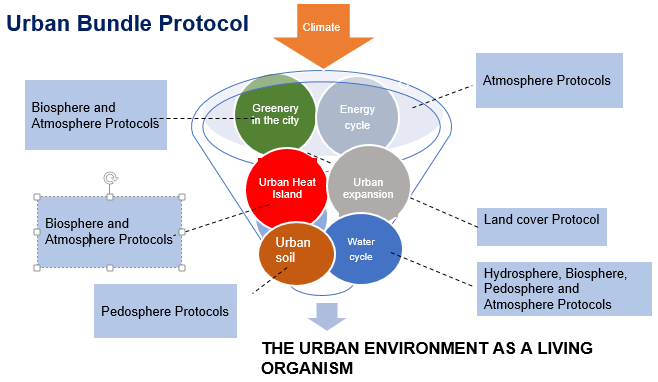


Figure 1. A schematic representation of the Urban Bundle Protocol.

**II. List of the GLOBE Protocols included in the bundle.**

Atmosphere Protocol

Air temperature

Relative humidity

Precipitation

Surface temperature

Clouds

Biosphere Protocol

Land cover classification

Biometry

Hydrosphere Protocol

Water temperature

Pedosphere Protocol

Soil characterization

Soil infiltration

Soil moisture

Soil temperature

**III. Science background and description of GLOBE Protocols**

Urban areas[[1]](#footnote-1) comprise less than 3% of the Earth’s surface; they have however developed mainly against a socio-economic paradigm, ignoring to a large extent the environmental impacts. Of particular concern for urban areas in our days, is the lack of balance between the natural, built and socio-economic environments leading, among others, to microclimatic changes, the expansion of urban areas at the expense of open/green spaces, the increase of anthropogenic heat sources and impervious surfaces leading to overheating, the increase of flooding following extreme rain events, the deterioration of air quality, etc.

Air pollution and heat islands/spots within the urban ecosystems have negative impact to human health especially for vulnerable groups; the latter increase energy use for cooling, lead to poor city energy efficiency, intensify energy poverty and result in socio-economic problems in general.

Air pollution and overheating problems are mainly recorded in medium and large cities. In particular air temperatures even higher by 6-8 degrees Celsius compared to rural areas are measured, while temperature differences exist even within the city as often the urban landscape and the urban planning features lead to the creation of thermal hot spots with considerable intensity and durability.

One of the main heat related effects of urban areas is the lack of green spaces. While in vegetated areas evapotranspiration transfers most of the incoming radiation into latent heat, in built up areas sensible heat is generated, which leads to the strong heat load of urban areas. In addition buildings strongly affect the flow patterns of wind and heat, practically keeping the heat close to the ground.

Table 1 provides a view of selected thematic areas to be studied within the urban environment along with the respective protocols as provided in the GLOBE Program.

|  |  |  |
| --- | --- | --- |
| Thematic category | GLOBE Protocol | Main parameters of the GLOBE Protocol |
| Atmospheric boundary layer  (Energy Cycle) | Atmosphere Protocol | Air temperature, relative humidity precipitation, surface temperature, clouds |
| Urban expansion | Biosphere Protocols | Land cover classification |
| Urban hydrology  (Water Cycle) | Atmosphere protocol  Hydrosphere, Biosphere, and Pedosphere Protocols | Precipitation  Evaporation, Soil infiltration, Water temperature |
| Urban soil | Pedosphere Protocols | Soil characterization, Soil infiltration, Soil moisture, Soil temperature |
| Urban heat island | Biosphere Protocols  Atmosphere Protocol  Hydrosphere Protocols | Land cover  Surface Temperature and air Temperature  Water Temperature |
| Greenery in the city | Biosphere Protocols  Atmosphere Protocols | Land cover classification, Biometry  Air temperature and surface temperature |

Table 1. A snapshot of selected thematic areas to be studied within the urban environment along with the respective protocols as provided in the GLOBE Program

**IV. Discussion of each GLOBE Protocol included in the bundle**

Air temperature is both a climatic and microclimatic parameter. Along with surface temperature, relative humidity and precipitation, it is possible to obtain a view of the climate and weather patterns of the area concerned.

Surface temperature is an important parameter for assessing the presence and intensity of the surface urban heat island. Essential for the estimation of the energy budget in an urban area as it controls sensible heat, i.e. heat transfer from the ground to the air above. Allows the definition of areas where cool (reflective) materials may be placed.

Air and surface temperatures support the estimation of the cooling effect of green spaces in cities. In addition to evaporative cooling, shading from trees can cool the lower atmosphere by reducing solar radiation reaching the ground and thus preventing the warming of the land surface and of the adjacent air. They are also important parameters for assessing the presence and intensity of the surface urban heat island and essential for the estimation of the energy budget in an urban area

High precipitation may result in flood events especially in areas covered with artificial (impervious) materials as compared to green areas (see also Land cover classification).

Evaporation is a cooling mechanism for cities. Evaporation is related to land cover as impervious urban materials such as asphalt and concrete, do not retain water for evaporation and quickly absorb and retain heat when exposed to solar radiation. Vegetation transpires water transforming soil moisture to atmospheric humidity

Clouds indicate convection in the atmosphere[[2]](#footnote-2), are linked to precipitation and low pressure systems and influence air and land surface temperature as they modify the energy budget of the land-atmosphere system, etc.

Land cover is important as knowing the type of materials at the surface is useful in terms of interpreting land and air temperatures as they depend on the albedo, the emission coefficient and the heat capacity of surface materials. Land cover classification provides a view of the type of materials at the surface (e.g. urban, green, industrial, soil). It also allows the understanding of changes within the city as well as of urban expansion, including its trends.

Evaporation is a cooling mechanism for cities. Evaporation is related to land cover as impervious urban materials such as asphalt and concrete, do not retain water for evaporation and quickly absorb and retain heat when exposed to solar radiation. Vegetation transpires water transforming soil moisture to atmospheric humidity.

The temperature of urban water bodies influences the local availability of water vapor as the higher the temperature, the higher the evaporation rate.

Soil infiltration supports the understanding of the capacity of the ground to store water, making it available for uptake by plants and soil organisms. Low soil infiltration may result in flooding following extreme rain events.

Soil moisture is the water stored in the soil and is affected by precipitation, temperature, soil characteristics, and more. These same factors help determine the type of biome present, and the suitability of land for greenery.

Soil temperature is required for calculating most belowground ecosystem processes, including root growth and respiration, decomposition, and nitrogen mineralization. Soil temperature is influenced by solar radiation, daily and monthly fluctuations of air temperatures as well as vegetation, amount of precipitation, etc.

Biometry reflects the properties of vegetation needed in order to classify land cover using the MUC system.

**V. Examples of case studies**

Case Study 1. Define and analyze the state of the thermal environment in a city.

An important case study is to define and analyze the state of the thermal environment in a city. This is because people who live in cities with burdened thermal environments, face increased health risks due to thermal discomfort and the increase of photochemical air pollutants, whereas they need to consume additional energy for their cooling needs. In order to achieve the objectives of this Case Study, you need to combine diverse environmental information and make use of several GLOBE Protocols.

Table 2 provides an extended list of environmental information which need to be monitored, links it to the GLOBE Protocols included in the Urban Bundle Protocol and also provides a description on the need to apply each of the GLOBE Protocols on a physical parameter basis.

|  |  |  |
| --- | --- | --- |
| Thematic category | GLOBE Protocol | Why do we need the GLOBE Protocol |
| Atmospheric boundary layer  (Energy Cycle) | Atmosphere Protocol | Air temperature and surface temperature support the spatial and temporal definition of the state of thermal environment in a city.  Precipitation allows the qualitative and quantitative estimation of the evaporation intensity, the latter being a significant cooling mechanism in a city.  Clouds influence the incident solar energy to the ground; thus their presence and extent in space and time, control air and surface temperatures. |
| Urban expansion | Biosphere Protocols | Land cover classification allows the correlation of air and – mostly – surface temperatures to the type of materials on the ground. It is important to have a close look on this correlation by completing Table 3. |
| Urban hydrology  (Water Cycle) | Atmosphere protocol  Biosphere and Pedosphere Protocols  Hydrosphere Protocol | Precipitation is critical for the water cycle and the extraction of conclusions on the dryness of the soil and the amount of soil moisture.  Soil infiltration supports the understanding of the capacity of the ground to store water, making it available for uptake by plants and soil organisms. Low soil infiltration may result in flooding following extreme rain events.  Water temperature influences the local availability of water vapor as the higher the temperature, the higher the evaporation rate. |
| Urban soil | Pedosphere Protocols | All soil related parameters (soil characterization, soil infiltration, soil moisture, soil temperature) are important to assess energy and heat fluxes between the ground and the air above. |
| Urban heat island | Biosphere Protocols  Atmosphere Protocol  Hydrosphere Protocols | Land cover is important for assessing measurements of surface temperature and air temperature (see also Table 3).  The higher the temperature of a water body, the higher its cooling intensity. |
| Greenery in the city | Biosphere Protocols  Atmosphere Protocols | MUC and GLOBE Observer Land Cover Classification support the spatial depiction of the areas in cities. In green areas, Biometry and GLOBE Observer Tree observations help define the properties of urban vegetation.  Air temperature and surface temperature in green areas allow the extraction of information on the cooling intensity of greenery. |

Table 2. A description of the application of the Urban Bundle Protocol in view of assessing the state of the thermal environment in cities.

An important application is the detection of the Urban Heat Island[[3]](#footnote-3) in cities. For this you need to collect air or surface temperatures – for different times of the day - in the city center and suburban or rural areas and define their difference in degrees Celsius. Be aware that you need to always compare the temperatures from the same areas so as to achieve the needed consistency.

Case Study 2. The impact of materials to the thermal environment in cities.

Different city materials develop temperatures which differ even if the amount of incident radiation is the same. This is due to their properties, for instance albedo, emission coefficient, and thermal capacity. In addition, even the same material may develop different temperatures in the event of changes in incident radiation (for instance due to shading) or material degradation.

In order to examine the role of materials in shaping the thermal environment in cities, you may use a thermal radiometer to record surface temperature for different surface materials. Fill Table 3 by taking three measurements (M1, M2, M3) at the same time of the day so as to produce the average value.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Type of material | Time of day | M1  deg Celsius | M2  deg  Celsius | M3  deg  Celsius | M average  deg Celsius | Cloud cover  (yes or no) | Comments |
| Bare soil |  |  |  |  |  |  |  |
| Asphalt |  |  |  |  |  |  |  |
| Grass |  |  |  |  |  |  |  |
| Wood |  |  |  |  |  |  |  |
| Cement |  |  |  |  |  |  |  |
| Car surface |  |  |  |  |  |  |  |
| Marble |  |  |  |  |  |  |  |
| Other |  |  |  |  |  |  |  |

Table 3. Recording of land surface temperature per type of material (M: measurement).

**VI. Summary**

Urban population worldwide has grown rapidly from 751 million in 1950 to 4.2 billion in 2018. Asia, despite its relatively lower level of urbanization, is home to 54% of the world’s urban population, followed by Europe and Africa with 13% each. Today, the most urbanized regions include Northern America (with 82% of its population living in urban areas in 2018), Latin America and the Caribbean (81%), Europe (74%) and Oceania (68%). The level of urbanization in Asia is now close to 50%. In contrast, Africa remains mostly rural, with 43% of its population living in urban areas. Overall, 55% of the world’s population lives in urban areas, a proportion that is expected to increase to 68% by 2050.

Given the above, it is important to secure that the environment in our cities is in good condition. To this end, do take action and use the Urban Bundle Protocol to examine the state of environment in the city where you live and try to identify those parameters which influence the quality of life of city dwellers. Communicate your findings to local authorities so as to better understand the state of environment in the city and also use the findings in support of policy planning. Your contribution is important for better cities as well as for raising awareness of urban environmental problems.

1. For the purposes of the Urban Bundle Protocol, an area is considered as urban when its population exceeds the threshold value of 50,000 inhabitants. [↑](#footnote-ref-1)
2. In particular the Cumulus (Cu) and Cumulonimbus (Cb) clouds, i.e. clouds with vertical extent. [↑](#footnote-ref-2)
3. An urban heat island (UHI) is an [urban area](https://en.wikipedia.org/wiki/Urban_area) that is significantly warmer than its surrounding [rural areas](https://en.wikipedia.org/wiki/Rural_area) due to human activities. The [temperature](https://en.wikipedia.org/wiki/Temperature) difference usually is larger at night than during the day, and is most apparent when [winds](https://en.wikipedia.org/wiki/Wind) are weak. [↑](#footnote-ref-3)