FICUP
An International Conference on
Urban Physics
B. Beckers, T. Pico, S. Jimenez (Eds.)
Quito – Galápagos, Ecuador, 26 – 30 September 2016

# Why Urban Physics and Why in Ecuador?

**Benoit Beckers**

Architecture and Urban Physics
Department of Building and Public Works (ISA BTP)
Université de Pau et des Pays de l'Adour
Allée du Parc Montaury
64600 Anglet
France

**Keywords:** Urban physics, Building physics, Environmental physics, Urban climate, Ecuador

**Abstract.** *The fundamental question addressed in the first international conference on urban physics is: why study urban physics? This paper allows us to respond to this concern. The subsidiary question is why in Ecuador and the Galapagos. The history of this part of the world shows us that we are not doing more than following the footsteps of prestigious scientists for more than three hundred years.*

## 1. Introduction

Comparing today’s cities worldwide, one is astonished by their many similarities in the form of streets, squares, facades, and other urban structures. This is due to a more and more noticeable convergence in construction techniques, but also in urban planning programs and territorial policies: downtowns with their tall towers of glass and steel, surrounded by large sets of brick and concrete blocks and residential areas sprawling far into the countryside.

In the past, cities were much more diverse: there were cities without streets such as Çatal Höyük, a Neolithic megalopolis of almost 13 hectares whose interiors were accessed from terraces connected to each other. There were also lake or lagoon cities such as the prestigious Venice, underground or semi-buried cities... These configurations were often excellent answers to climate assaults, because although other factors contributed to this (military defense and transport, among others), energy was expensive and the means to locally control the physical parameters of comfort such as temperature, air quality, lighting, and noise level were very limited. So, initiatives were taken in order to have the best general conditions on the urban scale, so that only small local adjustments should be necessary: some heating in homes, an increase of natural ventilation, candles for illuminating at night at the risk of setting fire to the neighborhood. However, neither of these ancient cities exceeded one million people from what we can tell.

Megacities of the Industrial Revolution have had to settle on other schemes and the past original solutions became obsolete, while new solutions were becoming increasingly uniform. Therefore, the new structures, which were very complex with their train networks, roads, running water, sewage, electricity, had to carry out special technology research. Indeed, several major scientific results came from urban problems of that time: the graph theory (anticipated by Euler to solve the problem of the bridges of Konigsberg), the formulation of the heat equation by Fourier, which sought to solve Paris heating problems, and even the definition of the black body by Kirchhoff to characterize the new whiteness of electric light in the lighting of cities.

In return, however, the most conscientious planners could hardly benefit from the scientific and technical advances, and only indirectly: metal structures, glazing, the development of transport, the lift and other inventions have allowed for both center densification and periphery sprawl. They were not well thought-out choices: it was not possible to rely on such partial and transitory calculations as the course of shadows, the visuals, the sound rays, or the finding of prevailing winds, to account for the whole power of financials, investors and speculators effectively - or even only a little.

In the second half of the twentieth century, two important ideas have been developed. First, bioclimatic architecture has connected climate with people´s activities and their comfort, establishing guidelines for the emergence of building physics. Then, environmental physics has developed its balance sheets of material, energy and momentum over crops and forests and - why not? - cities. At the beginning of this century, the progress of measure (and particularly telemetry) and computing allowed us to finally consider urban physics at the interface between building physics and environmental physics.

## 2. Urban Physics Worldwide

With these new resources, it becomes possible to map the Urban Heat Island [Pinson 2016], quantify the mutual influence between it and building consumptions [Masson 2016], and develop interdisciplinary studies taking into account air quality, climate comfort, and soundscapes [Gauvreau 2016]. With respect to numerical methods and their application to very large urban models, there are two main starting points: first, shortwave radiation [Beckers 2016] and longwave radiation [Nahon 2016], and, second, Computation Fluid Dynamics (CFD) methods [Montazeri 2016].

CFD simulations allow comprehensive studies on the effect of vegetation on a park in the urban environment [Toparlar 2016], but also on the very specific and potentially devastating phenomena related to windstorms [Romanic 2016].

Methods related to radiation, which can be heat, but also natural light [Paule 2016], give particular importance to the quality of the geometric model [Rassineux 2016], its level of detail [Besuievsky 2016] and are therefore utilized to calculate the specific characteristics of urban forms [Aguerre 2016], which then allow for the automatic optimization process [Vermeulen 2016].

These two steps would soon be combined in Finite Element Method (FEM) platforms applied to the city, which would help to better assess multiple physical aspects [Knopf-Lenoir 2016], but with significant computing time, which will justify in turn the use of methods such as model reduction techniques [Breitkopf 2016].

The most advanced work in this emerging field is often developed in Europe and North America, but also in important centers in Southeast Asia and Oceania. This allows for extensive studies of the urban climate in tropical megacities like Hong Kong [Wang 2016], or equatorial ones like Singapore [Nazarian 2016]. There are also studies on the specific characteristics of cities in arid climates [Massoud 2016] and Nordic ones or on Urban Heat Island in Arctic cities of the Russian far North [Salmonov 2016].

These studies are a fundamental part of the current research because considering the variety of climates on the globe, it is necessary to propose appropriate urban solutions, taking into account what is possible from historical solutions and adapting them to current conditions.

It is disappointing that the corresponding research does not have all the same reach or the same visibility, particularly in sub-Saharan Africa and Latin America; even though these two parts of the world have very important urban growth, with serious problems not only related to natural and industrial hazards, but also to energy supply deficits, air and soil pollution, and often poor quality of construction and maintenance.

The UN-Habitat program [http://www.unhabitat.org/] has therefore rightly been established in Nairobi (Kenya). After Vancouver (1976) and Istanbul (1996), the third Habitat conference will be held in Quito in October 2016 [https://www.habitat3.org/].

## 3. UrbanPhysics In Ecuador

In a relatively compact territory (ten times as big as Belgium), Ecuador meets four remarkable and differentiated climates: the Coast, the Andes, the Amazon and the Islands. As the name indicates, the country is located on both sides of the equator, and it is on its coast that the Humboldt Current, having enriched its cold, rich waters from Antarctica, the coasts of Chile and Peru, is changing its bearing to the open sea and the Galapagos Islands. The map in Figure 1, which represents this country, was drawn up in 1942 by the geographic services of the US army, at the time when the Galapagos Islands had acquired strategic importance against Japan. The Americans had set up a base there, and after the war, they left to the Ecuadorians the airport of Baltra and equipment for desalination. Thus populations could settle permanently on these islands, well-preserved so far by the lack of drinking water.

The population, a small forty thousand inhabitants, lives in a unique and much protected nature reserve, where any intervention is particularly exposed, starting with access to energy [Calle 2016] and the development of essential infrastructures, such as Baltra airport [Evans 2016].

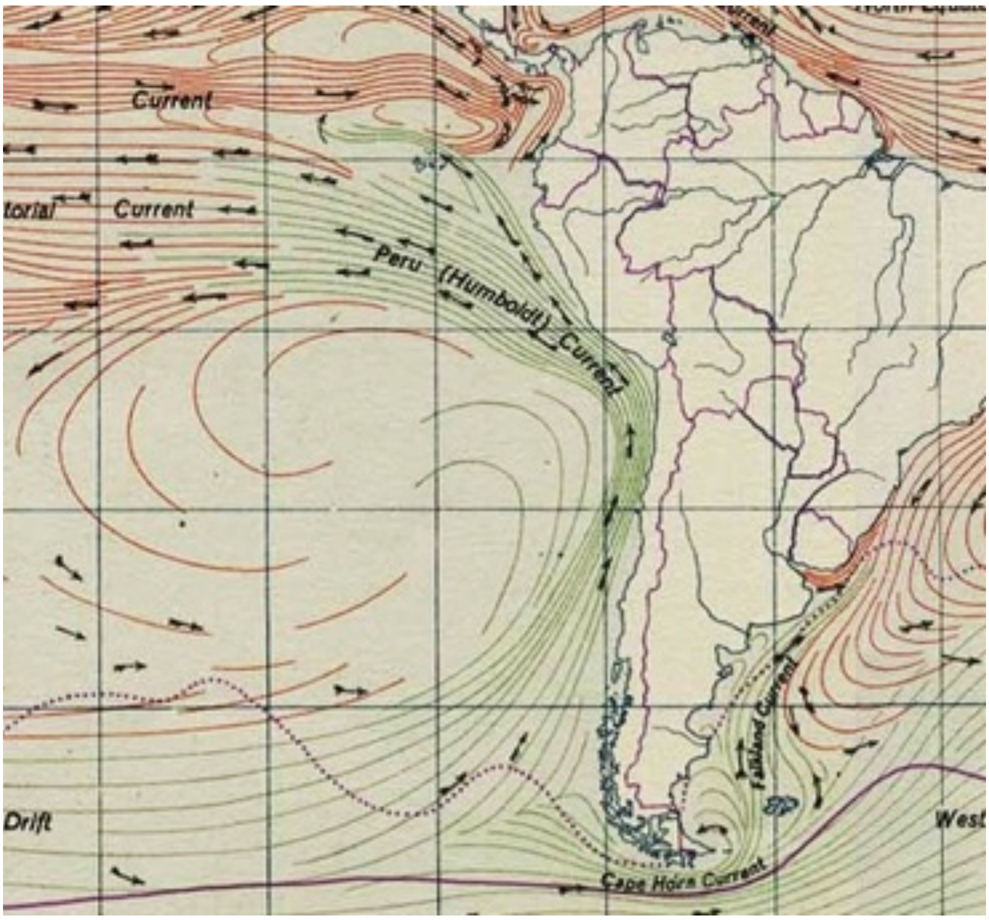


Figure 1: https://commons.wikimedia.org/wiki/File:Humboldt_current.jpg

The Ecuadorian Coast is one of those special places where life proliferates, on land and in the water: cocoa, bananas, shrimp, among many other species of flora and fauna. Some of the most remarkable and oldest cultures of pre-Columbian America have developed there, especially the Valdivias (3500 - 1800 B.C.) and the Chorreras (1200 - 500 B.C.). The "Museo Nacional

Quito" displays these extraordinary achievements. In this very hot and very humid climate, an appropriate architecture is of the essence [Torres Quezada 2016], and the Urban Heat Island of the great city of Guayaquil has to be limited [Palme 2016].

In the early sixteenth century, the Andean Inca civilization, originated from Cuzco, dominated Ecuador. It is in Quito that the emperor Huayna Capac learned of the existence of Spanish people, before dying in the south of the present-day Colombia, probably of smallpox, which shortly preceded the advance of the Conquistadores.

Quito is the second highest capital in the world (2850 meters), after La Paz (3660 meters) and before the megacity of Bogota (2640 meters). With an annual average temperature of 14-15 degrees in Bogota as well as in Quito, solar gains are welcome, but the access to natural light should rule bioclimatic architecture [Franco 2016].

Quito owes its beauty to a remarkably preserved colonial city, but more specifically to a superb location where ravines alternate with volcanoes [Aragundi 2016]. In the eighteenth century, this "volcanoes alley" formed the most accessible and open place around the equatorial line.

That is why Charles Marie de La Condamine (Paris 1701 - Paris 1774) chose to lead the "French geodesic expedition in Ecuador" there from 1735 to 1743 to determine the shape of the Earth. He was accompanied by the mathematician and physicist Pierre Bouguer (Le Croisic 1698 - Paris 1758), who published an "Essai d'optique sur la gradation de la lumière" in 1729 [Bouguer 1729], where he assessed the amount of light lost by passing through a given area of the Earth's atmosphere. The geodesic expedition left such memories in Ecuador that the country owes its present name to it, after the failure of Simon Bolivar's "Gran Colombia".

Another scientific expedition has left a deep impression on the region, that of Alexander von Humboldt (Berlin 1769 - Potsdam 1859) and Aimé Jacques Alexandre Goujaud, known as Bonpland (La Rochelle 1773 - Paso de los Libres 1858). In 1802, they conducted a vegetation survey of Chimborazo, considering altitude, climate, and topography. They began the ascent of the volcano, without reaching the summit at 6310 meters altitude. Nevertheless, they held the world record for altitude until 1804, when Joseph Louis Gay-Lussac passed 7000 meters, but in a hot air balloon.

Before that, Humboldt and Bonpland had met José Celestino Mutis y Bosio (Cádiz 1732 - Santa Fe de Bogotá in 1808). The Spanish doctor was the protagonist of the "Real Expedición Botánica del Nuevo Reino de Granada", the only genuine high-scale scientific enterprise realized in the American colonies of Spain, under the enlightened reign of Carlos III. This expedition, which lasted thirty years starting in 1783, allowed the scientists to collect and classify 20 000 plant species and 700 animal species in the territory of present-day Colombia. It allowed for the creation a group of scientists and local artists who participated in the independence movement, often paying for that with their lives.

Today, intellectual life has become less dangerous, and Ecuadorian researchers – or researchers established in Ecuador – are exploring new architectural forms in the Ecuadorian context [Suzuki 2016], the link between architecture and social life [Villacis 2016], the adaptation of sustainable urban planning approaches [Salmon 2016], and the feasibility of the transition to electric vehicles [Davis 2016]. In doing so, they develop, in the very particular physical and socio-economic context of their country, ideas that concern researchers worldwide.

Finally, we must mention one last significant scientific expedition that closely concerns Ecuador, probably the most famous one. In 1831, the young Charles Darwin (Shrewsbury 1809 - Downe 1882) embarked on the Beagle for an expedition that lasted five years. He explored the coasts of Brazil, Uruguay, Argentina, Chile, and Peru, crossing the Andes several times in search of geological strata and fossils of extinct animals. On the way back, during a stop at the Galapagos, he naturalized some birds that seemed to be of different species. After his return to England, John Gould observed that all these birds were finches, differing only by the shape of their beaks. For Darwin, it was the finding that led him, after much verification, to formulate his theory of natural selection.

Ten years ago, on June 23, 2006, the last passenger of the Beagle died in Beerwah, Australia, victim of a heart attack. Harriet was then 175 years old. This Galapagos turtle had been picked up by Charles Darwin, and then offered to a friend who took her to Australia. During the life of Harriet, the human population multiplied by seven. The whalers no longer stop in the islands in the best interest of the turtles. The hard whale fishing has stopped, but the seas are now plowed by container ships and the continents have seen a proliferation of cities and their suburbs, to cover a high percentage of the land surface.

## 4. Conclusions

If she had lived ten years longer, maybe Harriet would be moved to learn that some researchers would meet in her native country to discuss the future of human cities, their footprint on our planet, and their control by means of physical modeling, satellite imagery, and computers. But we would have ignored it, because the emotions of a turtle remain imperceptible to us.

## References

[Aguerre 2016] José Pedro Aguerre, Eduardo Fernández, Gonzalo Besuvievsky, and Benoit Beckers, *Sparse Matrix Solution for Computing Urban Radiation Exchange, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Aragundi2016] Sheika M. Aragundi, Alexandra P. Mena and Jenny J. Zamora Historical *Urban Landscape as a Descriptive Feature for Risk Assessment: the 'Quebradas' of Quito, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept.

[Beckers 2016] Benoit Beckers and Pierre Beckers, *Fast and accurate view factor generation, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Besuievsky 2016] Gonzalo Besuievsky, Benoit Beckers, and Gustavo Patow, *Skyline- control Based LoD Generation for Solar Analysis in 3D Cities, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Bouguer 1729] Pierre Bouguer, *Essai d'optique sur la gradation de la lumière, Claude Jombert ed., 1729*

[Breitkopf 2016] Piotr Breitkopf, Pierre Villon, *Towards reduced-order modeling of complex phenomena in urban physics, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Calle2016] Pedro Calle, Siebe Broersma, *Energy Strategies towards a Fully Sustainable Galapagos Archipelago, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Davis 2016] Davis, M.J.M., *An Electrifying Change: The Need to Introduce Electric Vehicles in Ecuador, And Its Potential Impact on the Energy Sector, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Evans 2016] John Martin Evans and Silvia de Schiller, *From Theory to Practice: Building Physics in Urban Design, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Franco 2016] A study of solar access in Bogotá: the Las Nieves neighborhood, R. Franco, P. Bright, J Benitez, and B. Beckers, F*irst International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Gauvreau 2016] Gauvreau B., Guillaume G., Can A., Gaudio N., Lebras J., Lemonsu A., Masson V., Carissimo B., Richard I. and Haouès-Jouve S., *Environmental quality at district scale: A transdisciplinary approach within the EUREQUA project, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Knopf-Lenoir 2016] Multiphysic Design of a Street Section, Catherine Knopf-Lenoir, David Muñoz, Raphaël Nahon, Benoit Beckers, *First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Masson 2016] V. Masson , J. Hidalgo, A. Amossé, E. Bocher, M. Bonhomme, A. Bourgeois, G. Bretagne, S. Caillerez, E. Cordeau; C. Demazeux; S. Faraut, C. Gallato, S. Haoues-Jouve, M.-L. Lambert, A. Lemonsu, J.-P. Lévy, N. Long; C.-X. Lopez, G. Petit, M. Pellegrino, C. Pignon, C. Plumejeaud, V. Ruff, R. Schoetter, N. Tornay, D. Vye, *Urban Climate, Human behavior & Energy consumption: from LCZ mapping to simulation and urban planning (the MApUCE project) , First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Massoud 2016] Badia Masoud, Benoit Beckers, and Helena Coch, *Sky Access versus Shading for Pedestrian Comfort in the Hot Tropical Climate of Jeddah, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Montazeri 2016] H. Montazeri, Y. Toparlar, B. Blocken and J.L.M. Hensen, *Numerical modeling of evaporative cooling using water spray systems for heat stress reduction in urban areas, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Nahon 2016] R. Nahon, O. Blanpain and B. Beckers, *Impact of the anisotropy of the sky vault emissivity on the building envelope radiative budget, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Nazarian 2016] Negin Nazarian, Tiffany Sin, Leslie K. Norford, *Impacts of Realistic Surface Heating on Outdoor Thermal Comfort, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Palme2016] Massimo Palme, Geovanna Villacreses, Andrea Lobato, Martín Cordovez, José Macias and Guillermo Soriano, *Estimating the Urban Heat Island Effect in the City of Guayaquil, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Paule 2016] Bernard A. Paule and Jérôme H. Kaempf, *Daylighting: an approach from urban to room scale, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Pinson 2016] L. Pinson and V. Masson, *Heat stress in urban area: data fusion of observations, modeling and geospatial information, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Rassineux2016] Alain Rassineux, Benoit Beckers, *A robust smoothed voxel representation for the generation of finite element models for computational urban physics, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Romanic2016] Djordje Romanic, Dan Parvu, Horia Hangan, *Downburst Reconstruction using Physical Simulation and Analytical Model with Application to Urban Environments, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Salmon 2016] Nicolas Salmon, Grace Yepez-Salmon, Marc Lotteau, *To evaluate the sustainability of urban planning projects through an LCA approach: example of application of the NEST tool and requirements for its use in the context of Ecuador and Latin America, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Samsonov 2016] Timofey E. Samsonov, Pavel I. Konstantinov, Mikhail I. Varentsov, *Object-Oriented Approach to Urban Canyon Analysis, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Suzuki 2016] Seiichi Suzuki Erazo, *Real-time material computation in architectural design: Experiments on the development of interactive form finding tools, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Toparlar2016] Yasin Toparlar, Bert Blocken, Bino Maiheu, GertJan van Heijst, *Computational analysis of an urban park's impact on the Antwerp microclimate, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Torres-Quezada 2016] J. Torres-Quezada, A. Pages-Ramon, H. Coch and A. Isalgué, *Radiative Performance Assessment of Two Roofs in Mediterranean and Equatorial Climates, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Vermeulen 2016] T. Vermeulen, C. Knopf-Lenoir, L. Merino, P. Villon, and B. Beckers, P*eriodic 3D model to optimize urban shapes for solar radiation, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Villacís 2016]Enrique V. Villacís, María L. Rodriguez, Cynthia C. Ayarza, and Klaus Rueckert, *Pertinence of social inclusion design methods in communities, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)

[Wang 2016] Weiwen Wang, Yong Xu, and Edward Ng, *Application of Large-Eddy Simulations in Evaluating Ventilation over 3D Building Data Retrieved from Satellite Images, First International Conference on Urban Physics* (Quito – Galapagos, 2016, Sept. 26-30)