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GENOVA UNIVERSITY PRESS

International Conference on Urban Comfort and Environmental Quality URBAN-CEQ

28-29 September 2017 - University of Genoa, Italy

Edited by

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UNIVERSITÀ DEGLI STUDI
DI GENOVA

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URBAN-CEQ
International Conference on Urban Comfort and Environmental Quality
28-29 September 2017
University of Genoa, Italy

This volume contains the blind peer reviewed papers accepted for the International Conference on Urban Comfort and Environmental Quality held at University of Genoa, Italy, during 28-29 September 2017. The papers provide a current snapshot of leading research on urban comfort and environmental quality

Editor
GENOVA UNIVERSITY PRESS
Piazza della Nunziata, 6 16124 Genova
Tel. 010 20951558
Fax 010 20951552
e-mail: ce-press@liste.unige.it
http://gup.unige.it/

ISBN: 978-88-97752-91-2

Print on September 2017

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FOREWORD

More than two thirds of European citizens live in cities, where many environmental problems are concentrated, such as lack of thermal comfort and poor air quality, which seems to be also responsible for life-threatening conditions. It is more and more necessary to link urban regeneration strategies to objectives of environmental quality improvement. That is why many researchers, working in Universities and Research Centres, are focusing their activity on the evaluation of environmental quality of urban areas, considering a wide range of environmental problems and air quality and their effects on citizen life conditions and health.
The Architecture and Design Department (DAD) and the Department of Civil Engineering, Chemistry and Environmental Engineering (DICCA) – two departments of the Polytechnic School, University of Genova – decided to organize the International Conference on Urban Comfort and Environmental Quality (URBAN-CEQ) to gather architects and engineers committed to environmental quality research. These are specialists of fluid dynamics, of urban design and urban planning using tools and models to analyse the urban environmental quality, aiming to organize strategies and technologies to improve life conditions.
The Organizing Committee includes, from one side (DAD), professors and researchers belonging to the Italian Society of Architectural Technology (Società Italiana della Tecnologia dell'Architettura –SITdA), from the other side (DICCA), the wind engineering expertise from the school of Genova, which is worldwide recognized for its longstanding tradition. The organization of the conference rises from a cultural context of scientific disciplines integration and relies on the cooperation of a wide international Scientific Committee.
Key topics of the conference call are urban heat island studies; dynamic simulation tools to study pollutants dispersion and outdoor thermal comfort and building heating demand; blue-and-green technologies; air quality improvement strategies, etc. Researchers from many Countries have answered to the call sending papers, 28 of them have been (blind) reviewed and selected.
In this proceedings book selected papers are divided in four sections: Models and tools for urban climate studies, Urban comfort studies, Green and Blue strategies and technologies for urban environment, Heat energy demand and indoor comfort. They are a great example of multidisciplinary approach to complex and challenging problems of our society.
Keynote speakers are renowned international experts in the field of environmental quality and urban areas: Prof. Thomas Auer - Chair of Building Technology and Climate Responsive Design, Technische Universität München - and Prof. Bert Blocken - chair Building Physics and Urban Physics at the Unit Building Physics and Services (BPS) of the Department of the Built Environment at Eindhoven University of Technology in the Netherlands. The Organizing Committee acknowledges both for sharing their experience with the attendants, inspiring new development and research topics.
The Organizing Committee also wishes to thank all the authors and reviewers for their contribution, with the hope that this will be the first of a successful series.

Air movement representation as a tool for urban and architectural environmental quality

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Abstract*

Air movement is a measurable physical phenomenon that produces indirectly measurable effects on people and on the environment. It is an essential prerequisite for the comfort and the hygiene of the built environment and it is highly relevant to the passive cooling strategies. The relationships between air movement and built environment have to be analysed under a multi-scale vision. They fall within the field of urban and architectural design because they can be influenced by artificial expedients, although they are always caused by natural factors. This paper discusses the need for a complete and objective representation of different kinds of air movement, to improve the urban and architectural design and to integrate the knowledge and the assessment of the built environment. The proposal for a graphic standard is partially described, aiming to contribute towards a codified and multi-scale representation of the air movements that can be considered as a tool for environmental quality, both in the maintenance or the conservation activities and in the transformation processes.

1 The role of the air movement in urban and architectural environmental quality: the need for graphic standard

Air is an essential environmental element for living beings, along with light, water and heat. *Exchange* and *Move* of air have been recognized as *functional convergences* between nature and buildings, focusing on the morphological adaptation (Badarnah, 2017). But air movement involves a wider field of interest, if seen as a measurable physical phenomenon that produces indirectly measurable effects on people (individuals or community) and on the environment (natural and built one). Many features of the vernacular architecture prove that the traditional approach to buildings was based on a shared awareness of these effects, which can be both beneficial and damaging.

Air movement is an essential prerequisite to achieve comfort and environmental quality of the built environment, both indoors and outdoors. Even if some natural physical factors (i.e. temperature and pressure) often increase and always cause air movement, it is a basic topic of architectural urban and environmental design, mainly because it can be influenced by artificial expedients. Although the multifaceted role of air movement has been studied from different perspectives (anthropocentric, environmental and engineering), a methodological synthesis is needed to face the concept of *breathing architecture* both in the existing settlements and in the new ones (Stavridou, 2015).

Two interlinked aspects in the role of the air movements in environmental quality can be underlined to contribute to this synthesis: the positive hygienic consequences and the energy-saving potential.

The exchange of air is the way to expel the pollutants and to avoid the formation of mould and dampness, preventing the *Sick Building Syndrome* (Apter *et al*., 1994; Seppänen and Kurnitski, 2009). At a broader scale, the air movement could be a main factor in improving the urban air quality, contributing to the urban health (Kjellstrom, 2007), even if they aren't sufficient to reduce the global air pollution. At an urban level the natural ventilation is frequently identified (with vegetation and high albedo materials) as one of the basis of a concurrent approach in the mitigation of the *Heat Island*

* This paper reports some results of research and didactic activities driven under the scientific responsibility of M. L. Germanà. She has written the text; S. Vattano and A. Tavolante have contributed to the literature review and to the selection of the figures. The par. 2 has been improved by S. Vattano's skills in the architectural representation.

effect (Shahmohamadi, 2010). As the relationships between the geometry and density of the urban fabric and the wind flow affect the health and comfort conditions of the urban areas, the interventions on the built environment must focus on these features (Rajagopalan, 2014), even if the constraints of existing settlement may restrict the possibilities of action.
The air movement makes possible the air exchange that is a major contributing factor of the cooling strategies at an urban and building scales: the environmental cooling through air movement (in addition to the control of external thermal inputs through solar control, insulation and thermal capacity) characterize the main passive cooling techniques (Santamouris, 2005). The natural ventilation, generated by outflow and inflow of air and increased by pressure and temperature differences, makes a sizable contribute to the NZEB (Nearly Zero Energy Buildings) goal, laid down by the European Community in 2010 (EU, 2010). In fact natural ventilation is 'passive' since it doesn't use equipment or engineering systems with energy consumption, and it is generally preferable to mechanical ventilation not only due to energetic issues, but also in consideration of the general well-being of occupants and users (Al horr, 2016).
For these reasons, hygienic and energetic performances are the features of cities and buildings in which the air movement plays the main role in attaining multiple Sustainable Development Goals (UN, 2015).
Air movement includes various phenomena with regard to the built environment that should be taken into account under a multi-scale vision, to be suitably directed and optimized for their better use in the urban and architectural design. The wider phenomenon of the prevailing winds (*territorial-scale winds* related to the macroclimate and *local-winds* related to microclimate) needs to be observed within a territorial area, considering some physical-geographical elements, as the specific geomorphological and hydrological features.
The urban and district levels need an intermediate scale, that focuses on the relationships between natural and artificial factors, which affect the urban climate: the air flows go across the urban fabric, meeting obstructions or being canalised and transforming their direction and intensity.
Within an organic vision, each building is featured by a different ability to breathe, that depends on several factors, as its shape and orientation and the characteristics of the openings (layout, size and typology). Every single building can be observed as a sort of air-system, in which the air movement follows a specific flow, dotted by elements that work in supply, distribution and extraction of the air, contributing both in terms of energy saving and of thermo-hygrometric comfort.
Finally, in a smaller scale, air movement plays an important role in improving the environmental performances of some main technological components, as in ventilated and micro-ventilated envelope.
All these typologies of air movement, originated by external factors (winds) or by internal causes (stack effect), have consequences on the environmental and health performances of the urban areas and buildings. Their standard graphic representation is essential to integrate/update/improve the usual dimensions of the urban and architectural design, since the early and subsequent definition phases of the design solutions. A subjective or artistic representation of air movement does not encourage the exchange of experiences that is strategic in the general scientific advancement/upgrade. After decades of research in this field, the time has come to encode a graphic standard in the representation of air movement to obtain a more effective and shareable knowledge about it.

2 State of art in the representation of air movement

Many examples of air representation in artistic or graphical expressions lead to confirm that it is easier to represent the effects of the air than the air itself, without taking into account the metaphorical or mythological references (Nova, 2011). In fact, the air movements are not visible, even though their effects are well recognisable and permanent in the landscape and buildings (Fig. 1). Even the standardized scales to rate the wind (like the Beaufort Wind Force Scale) are based on their consequences, at sea and on land.

Figure 1. The recognisable and permanent effects of the wind on the landscape and on the built environment. Views of Favignana island (ph. by M. L. Germanà November 2016).

Since the air movement has become a part of the environmental architectural design, the need for their direct representation has arisen. The state of the art in the air movement representation includes more than fifty years of research and application efforts. In the second half of the 1950s Victor Olgyay first proposed a scientific methodology in bioclimatic design, applicable case by case to each climatic zone, that still constitutes an important reference (Olgyay, 1963). Olgyay’s ground-breaking methodological attempts were accompanied by very strong efforts in representing the effects of the wind on the built environment observed at territorial, urban and building scale, studying how the air flow affects the local microclimatic variables, therefore the contour conditions, and the actual impact of wind on buildings. These representations are very effective, especially if one refers to the technological advancement of that time (Fig. 2).

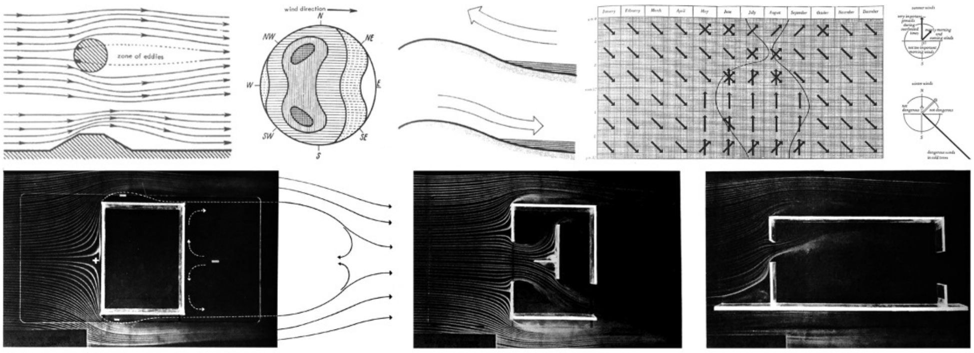

Figure 2. Above, the air representation at territorial scale (Olgyay, 1963: figg. 97-98; 100; 183-184). Below, the air representation at building scale (Olgyay, 1963: figg. 201; 214; 218).

In the last decades, many studies have been devoted to the on-going research of a generalizable method able to support the urban and architectural design solutions in pursuing sustainability. In the same time, an intense normative production and many training activities within the professional associations have approached the issues of environmental sustainability, energy saving and building energy performance certification. In most of these experiences, the air movements have been represented without a graphic standard: the literature review often shows, on one hand, the confirmation of Olgyay’s representation and, on the other hand, the application of his method to singular study cases. The suggestion for drawing the airflow diagram, by steps starting from the summer prevailing wind direction and proceeding through a trial-and-error process, is an interesting example of ventilation design guide based on simple graphic tools (Fig. 3).

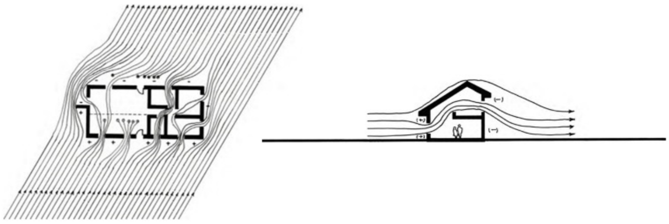

Figure 3. The Airflow Diagrams representing the air movement in plan and section (Lechner, 2015 p. 306).

The usual technical drawings (plans, sections and perspective or axonometric projections) have been commonly supplemented only by representations of airflows through arrows, larger outdoors and smaller indoors. In addition to the dimensional variation, which seems to indicate the mass of air, a colour variation (from green or blue to red) can be seen, which also allows to argue the temperature variation along the flow. The graphic representation attempts have included three-dimensional arrows placed in perspective or axonometric views in correspondence of changes in form or layout of the building (Fig. 4). Also at the urban scale, the schematic configurations of the interaction between ventilation and built context have shown the effort to represent the main aerodynamic trajectories of air around the built environment.

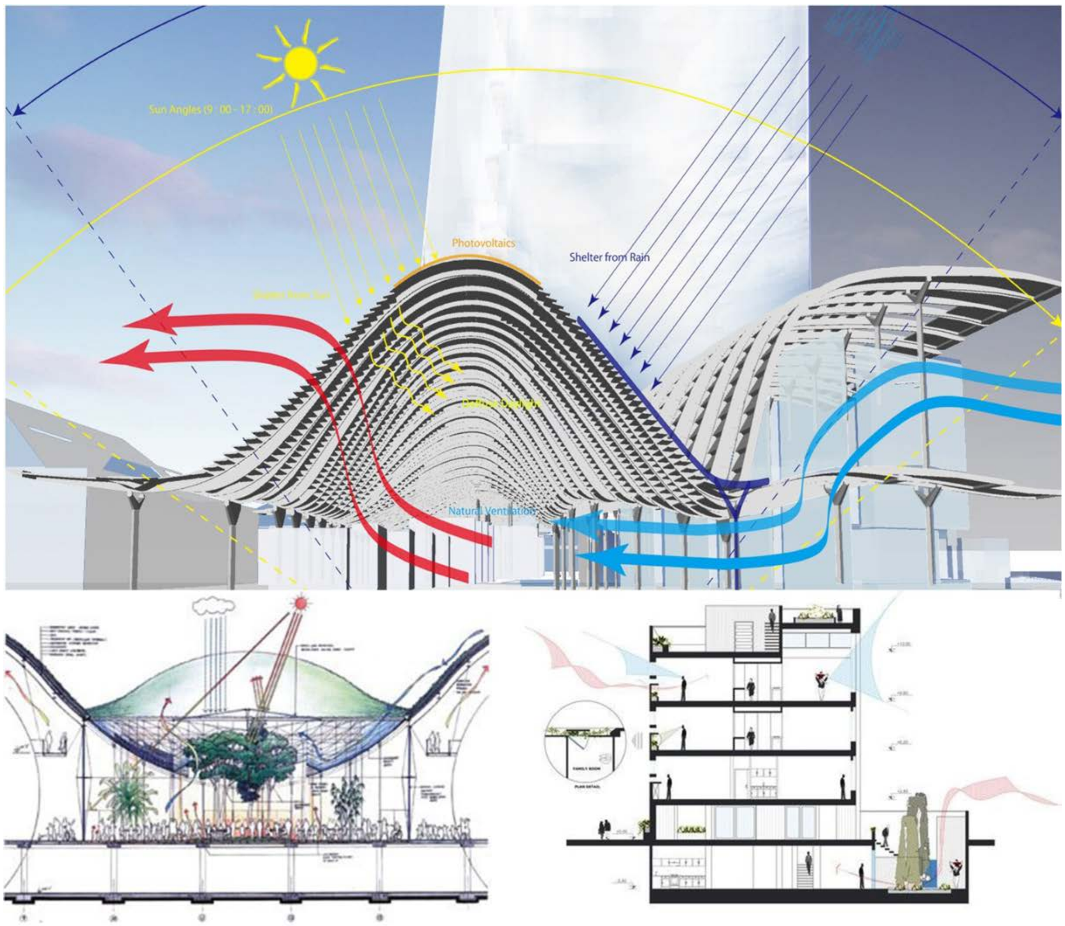

Figure 4. Examples of different air representation in contemporary architectural design. Above: *Singapores' New Eco-Complex, South beach.* Bioclimatic section. Project by Norman Foster 2007 (*http://inhabitat.com/foster-partners-new-green-complex-for-singapore/)*. Below on the left: *California Academy of Sciences*. Piazza airflow. Project by Renzo Piano 2008 (*http://www.arcspace.com/features/renzo-piano-/california-academy-of-sciences/*). Below on the right: *House no.2*, *Isfahan-Iran.* Bioclimatic section. Project by SarSayeh Architectural Office 2015 (*http://www.archdaily.com/787481/house-no-2-sarsayeh-architectural-office*).

Recently, the representation of the air movement has achieved previously inconceivable levels. Thanks to satellite images, geographical representation and meteorological data are available to everybody. For instance, the Air Quality Index and the wind velocity in every part of our planet are accessible for all in real time (Fig. 5).

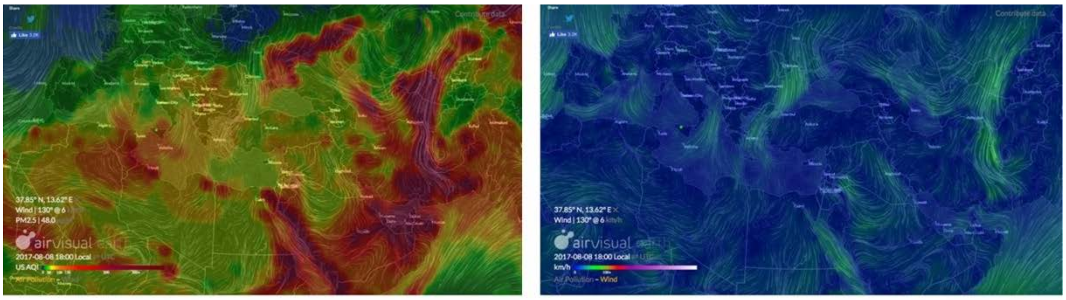

Figure 5. Air Quality Index and wind situation in Mediterranean Area in real time. August 8th 2017, 18:00. (*https://airvisual.com/earth*).

Similarly, today the architectural design has many available digital tools that achieve a hyper-realistic representation in an apparently easy way. The current digital revolution has deeply changed the architectural drawings, both in an operational sense and in their use. The air movements, for instance, are widely represented in 2D or 3D models as fluids interacting with built environment at the different scales. The most common software products in the field of natural ventilation in buildings use Computational Fluid Dynamics to simulate airflows with the aim of assessing the effectiveness of the ventilation system in different conditions. This allows detecting air intakes through the configuration of irregular arrows or irregular surfaces that represent the direction and concentrations of air at certain points of the building. The fluid-dynamics study is also deepened through software that can control data from the urban scale to the detail of the single object. The simulations performed, albeit at different degrees of detail, show a single interactive symbol representing the airflows, with the chromatic distinction related to the variation of velocity. This kind of representation has been improved both in new design and in the assessment of existing settlement, also of historical interest (Pelliccio, 2016).

There is no doubt that these representations are very helpful in integrating the airflow analysis in the urban and architectural design process (Fig. 6). In fact, these newer representations are easily readable also without specialist skills and offer a useful synthesis of the phenomenon. However, these images cannot establish a unified relationship between data management and information provided. This makes the sharing of the knowledge and the interoperability between several fields of research difficult. In the same way as the general trend towards a hyper realistic representation increasingly confuses the observer (in fact the digital drawings look often more real than a picture), the representation obtained by specific software solutions poses the risk of an uncritical vision, unable to make understandable the complex and multi-scalar phenomenon of air movements.

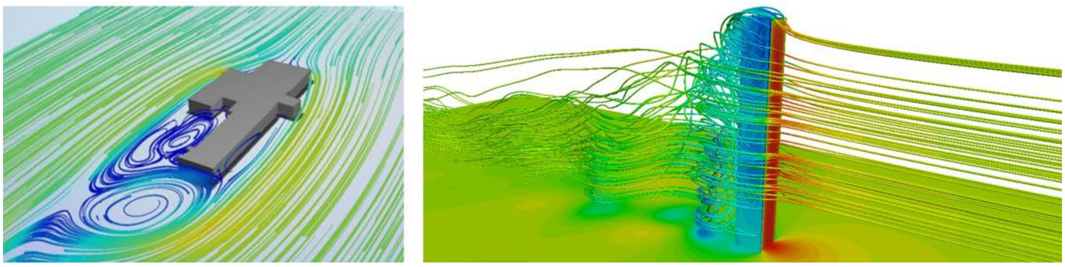

Fig. 6. Images of the *Wind & Airflow Strategies Course* (http://auworkshop.autodesk.com/courses/wind-airflow-strategies-course).

3 A methodology for a multiscale representation of the air movements

Some recent research and teaching experiences have given the opportunity for contributing to a graphic standard of air movements in a coherent multi-scale vision. A bioclimatic analysis has been done on diverse Sicilian cases of study (historical urban centres, archaeological sites, and single buildings of different epochs and uses) attempting to improve a repeatable method featured by multi-scale coherence, that allows a critical assessment of the air movements in a specific site, intending to increase the awareness of the design choices.

This analysing method aims to be repeatable regardless to the specific objective. Its results can be summarised in an improved understanding of the air movements useful to: a more complete knowledge and a more conscious intervention on the existing settlements; a more sustainable environmental design for the new buildings and urban areas. The theoretical basis of this aim is that the multifaceted architectural quality mostly depends on the relationships between the built environment and its context. The analysis of the environmental aspects, like the different kinds of air movement, is just a part of these relationships, important for some issue, as the hygienic and energetic performances of inhabited settlements, or the physical conservation of historical built heritage.

These experiences have allowed evaluating the urban and building characteristics, linking them to the action of dominant winds and offering a new interpretation that suggests original levels of understanding. The multi-scale analysis methodology starts with a series of geographic, topographic and meteorological data, taking into account the morphological features at the territorial scale. Through open access data obtained from the nearest meteorological stations, a graphical synthesis represents the general situation of the prevailing seasonal winds in the site. Different-coloured arrows are drawn in aerial photogrammetric views downloaded from https://earth.google.com/web/. A common caption, implemented referring to the Mediterranean wind rose, guides in the selection of the arrows' colour suggesting the temperature of the prevailing winds; the tip of the arrows indicates the speed, according to the Beaufort scale. The territorial scale analysis includes the altitudinal sections, where the arrows show the flow variation with respect to the local orography. A symbol distinguishes the reference season (Figg. 7-8).

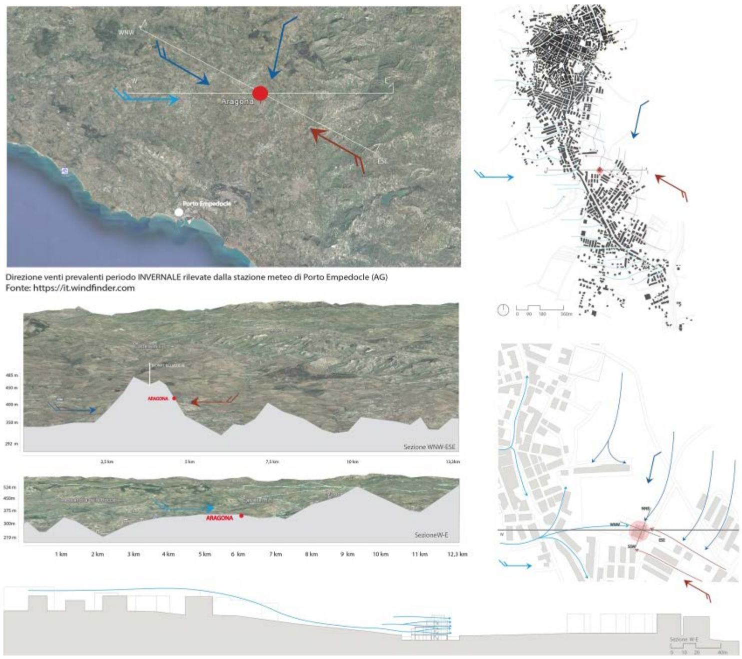

Figure 7. Air movements' multi-scale analysis: prevailing winter winds at territorial and district scale. Preparatory study for master diploma design of intervention on an unfinished building in Aragona, near Agrigento (F. Vella 2017).

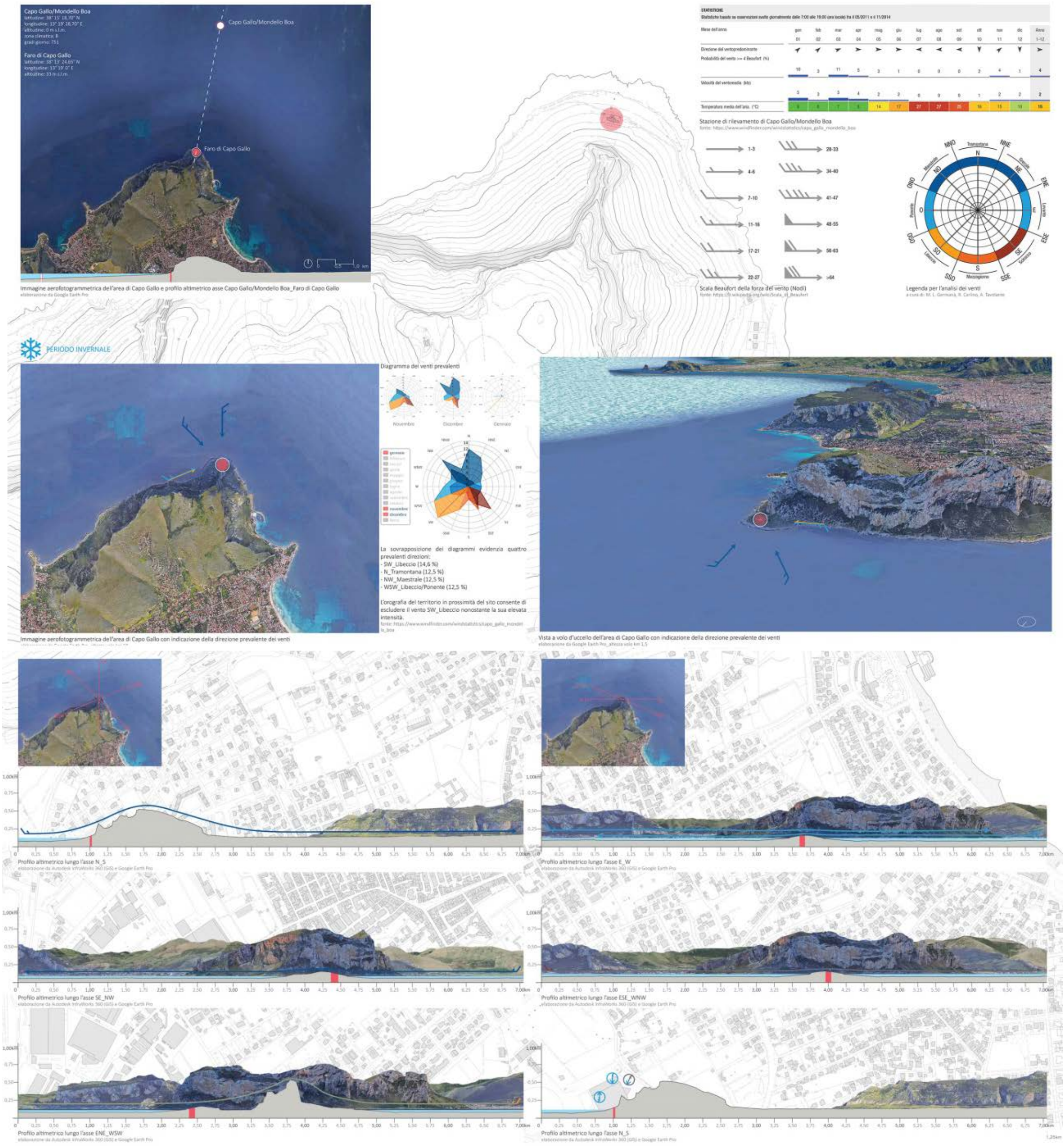

Figure 8. Air movements' multi-scale analysis. Above prevailing winter winds at territorial scale. Below altitudinal sections showing winter (on the left) and summer (on the right) winds. Preparatory study for master diploma design of intervention on the lighthouse of Capo Gallo a Palermo (C. Mendola, 2017).

The following analysis at urban and district scales considers only the wind that do not find any obstacle at the territorial scale. The arrows retain the same colour to remark the wind's direction; the straight lines became sinuous crossing the urban fabric or other barriers, in accordance to the known effects of variation of the airflow. At the building scale, the coloured arrows point out the spaces featured by a critical lack of natural ventilation. In the sections, the cross winds perpendicular to the plane of the representation are marked with a circular symbol that contains a little arrow, upward in case of following wind; downward in case of headwind (Fig. 9). In case of slope winds, thermally created winds that blow up or down in the same direction reversing the way by day and night, the graphical standard described above is not appropriate. In this case the arrows indicate the direction while the sun and moon symbols indicate the way (Fig. 10).

Further factors of air movement have their origin inside the building rather than outside. These kinds of air movements are also important in the health performances and in the passive cooling strategies, perhaps more than those have external origin. In fact, a careful solar design can contribute to the natural ventilation, both indoors and outdoors, even in lack of external factors. Another graphic standard has been studied for these further air movements that is not covered by this paper, due to editorial limitations. It differs according to the air movement that is valuable in the spatial units or in the technical components (like the building envelope).

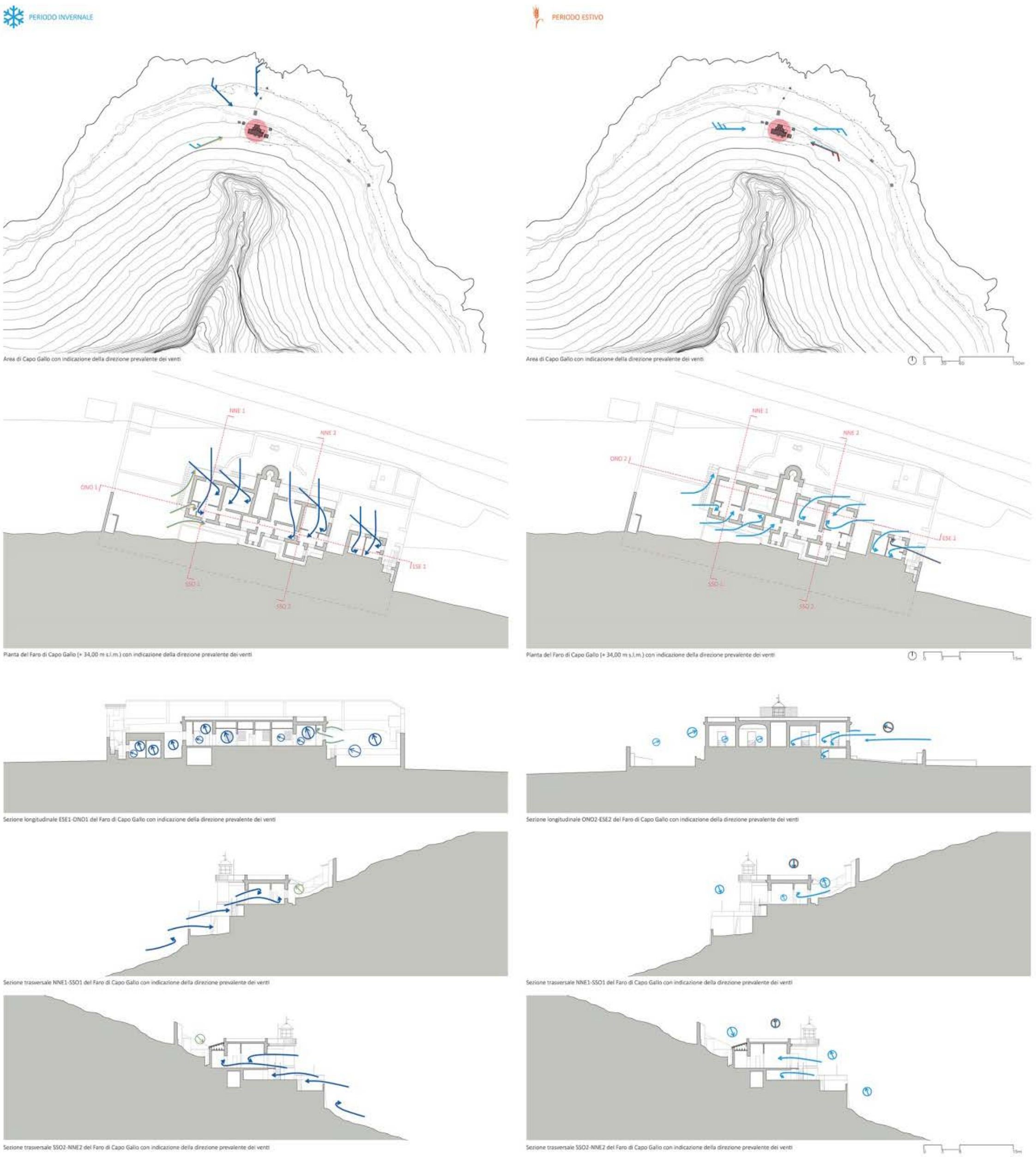

Figure 9. Air movements' multi-scale analysis: prevailing seasonal (winter on the left and summer on the right) winds at territorial scale at building scale. Preparatory study for master diploma design of intervention on the lighthouse of Capo Gallo a Palermo (C. Mendola, 2017).

4 Conclusions

Different kinds of air movement, featured by internal or external origins, relate to the built environment. There is a need of a multi-scale analysis for a comprehensive understanding of the interactions between the air movement and the architecture, within a wider vision of its contextual relationships. Two interlinked aspects in the essential role of the air movements in achieving urban and architectural environmental quality, both indoors and outdoors, have been underlined: the positive hygienic consequences and the energy-saving potential.

A codified representation is required to include the air movement among the usual dimensions of the urban and architectural design, also in order to encourage the exchange of experiences that is strategic in the general scientific advancement. After decades of research and experiences in the environmental architectural design, the time has come to address the attempt to encode a graphic standard in the representation of air movement. This does not run counter the digitalization of the architectural representations, but it tries to eliminate the backlog comparing to the representation of other aspects, like the buildings materials.

An analysing and representing method has been partially described here, that aims to be repeatable, regardless to the specific objective. The results can be summarised in an improved understanding of the air movements, useful to: a more complete knowledge and a more conscious intervention on the existing settlements; a more sustainable environmental design for the new buildings and urban areas. It would be worth continuing the experimentation, applying this analysing and representing methodology to more study cases, in order to improve a graphic standard to the different kinds of air movement, bestowing therefore an image to something that is invisible in itself.

Figure 10. Air movements' multi-scale analysis: slope winds at district and building scale. Preparatory study for master diploma design of intervention on an historical building in Sinagra (M. Bonina, 2017).

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Urban-CEQ international conference focuses on the evaluation of environmental quality of urban areas, considering a wide range of environmental problems, such as thermal comfort and air quality, and their effects on citizen life conditions and health. The event aims to be a meeting between specialists of fluid dynamics, designers and managers of urban areas in order to identify areas of frontier research, the sharing of useful targets for the improvement of urban environmental quality.
More than two thirds of European citizens live in cities, where many environmental problems are concentrated, such as lack of thermal comfort and poor air quality, which seems to be also responsible for life-threatening conditions. It is more and more necessary that the urban regeneration strategies are linked to objectives of environmental quality improvement.

ISBN: 978-88-97752-91-2