Methodological Notes on the Spatial Analysis of Urban Formation

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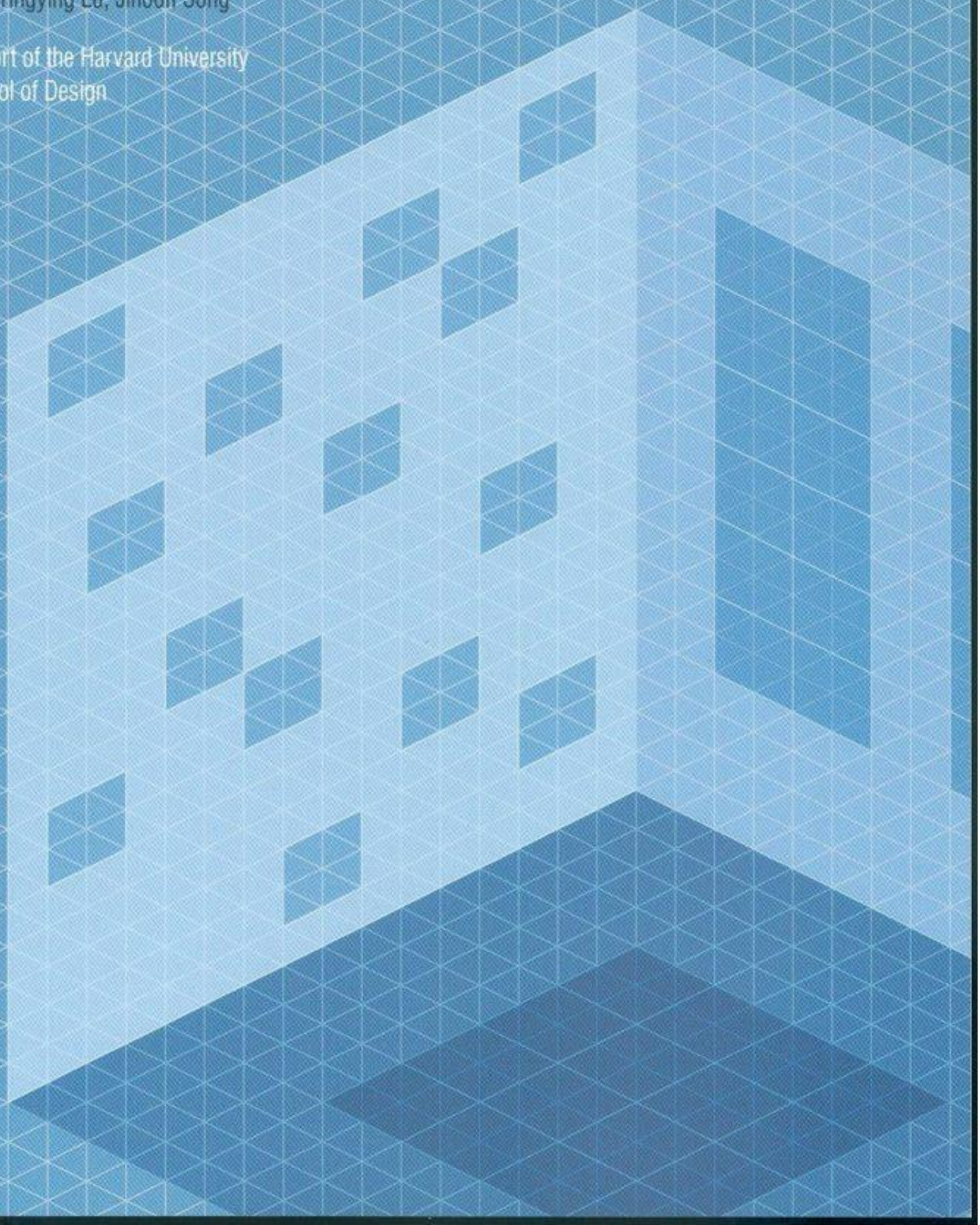

k. Modeling Building and Block Level Environmental Responses

An important aspect in the spatial analysis of urban formation is the evaluation of environmental response and performance of buildings and building block ensembles that make up the essential fabric of urban settlements. Nowadays, this can be accomplished through a variety of software and modeling applications with regard to climatic aspects like wind flow, daylighting potential, thermal response, including, with some difficulty, heat island effects as well as thermal comfort. Also of analytical interest is energy use, including embodied energy and walkability in the interests of reducing carbon footprints. In many cases, the building, block, and street structure of the area in question is modeled in basic three-dimensional envelope form, often in a Rhino-based design and analytical environment like the one shown here for the Urban Modeling Interface (UMI) developed by the Sustainable Design Lab at MIT.

(i) Wind Analysis

Figure 279 outlines three urban environments of varying building and urban block arrangements that were subject to the analysis of prevailing wind patterns using Flow Designer software and climate data in the form of Energy Plus Weather Data. The Manhattan example represents small block configurations and a mix of high- and mid-rise building configurations, Chuo-ku in central Tokyo represents a small block and low-rise configuration, whereas the Beijing Central Business District (CBD) represents a relatively open superblock arrangement with high-rise building.

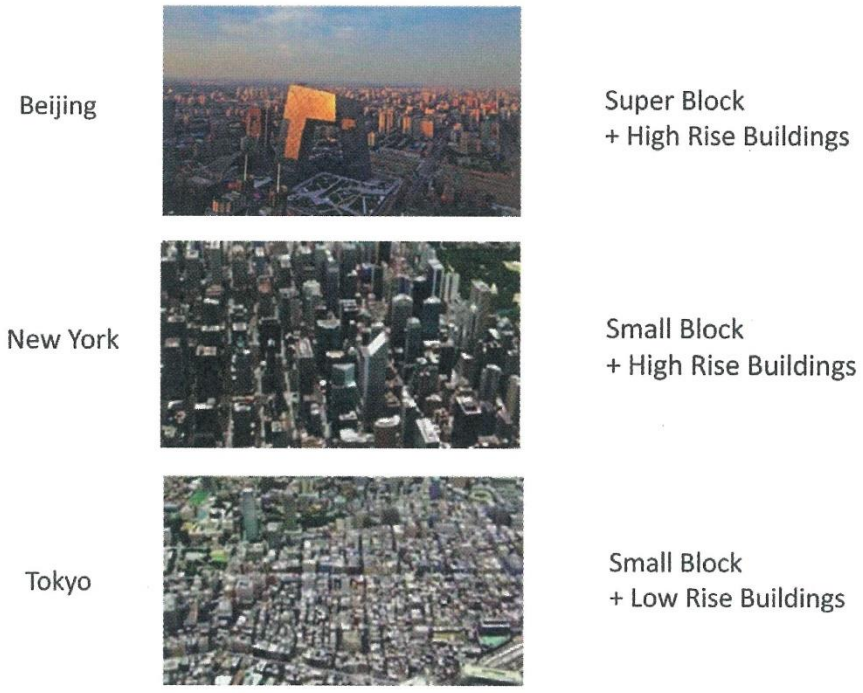

Fig. 279 Three Cases for Wind Analysis

Figures 280 and 281 describe the study area in lower Manhattan, New York in its broader and local context. The mid-rise area subject to analysis centered on the Washington Square and New York University area of the city. As shown, there are several different building heights.

Fig. 280 Manhattan Study Area in Broader Context

Fig. 281 Aerial Oblique View of the Study Area

Figures 282 and 283 represent the Rhino-based three-dimensional model of the building envelopes and open spaces within the study area and in planimetric view of the block layout. The average block size, as shown was 160 meters by 80 meters, with varying street and road widths.

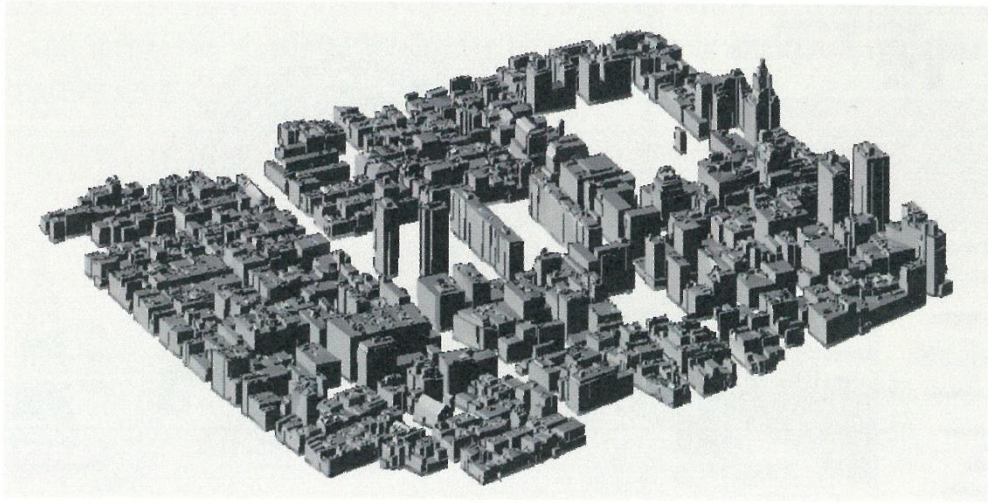

Fig. 282 Three-Dimensional Model of the Study Area

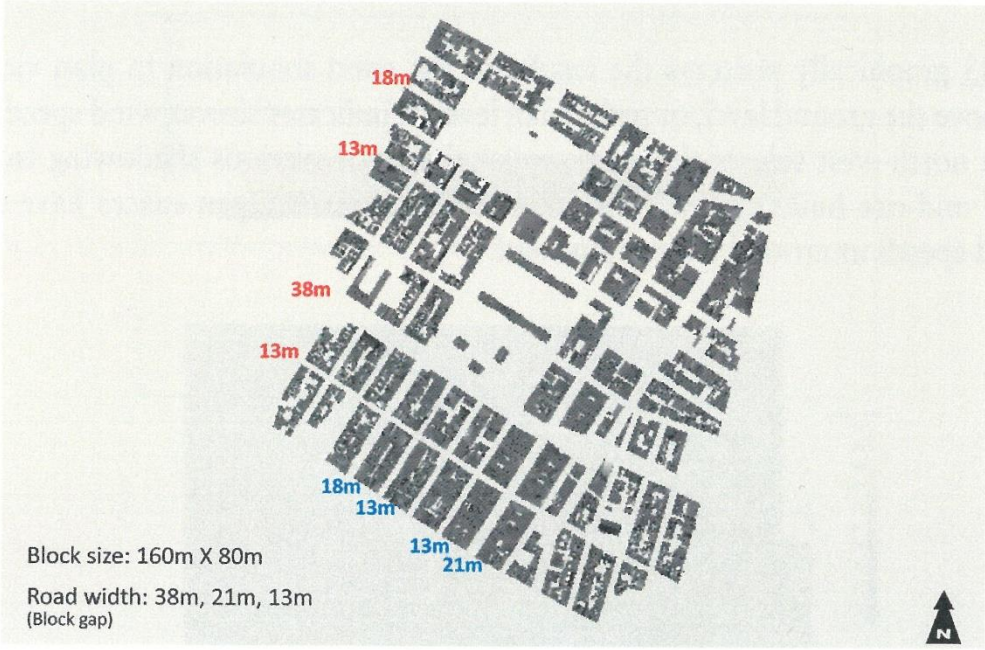

Fig. 283 Block Layout of the Study Area

Figure 284 shows climatic data applicable to the study area. Included are a wind rose with various speeds of wind flow, alongside of data about temperature and relative humidity. Clearly in this analysis, the wind-related data is most important, indicating a prevalence from a southerly direction during the winter months, at an average speed of 8 meters/second at a 40-meter elevation.

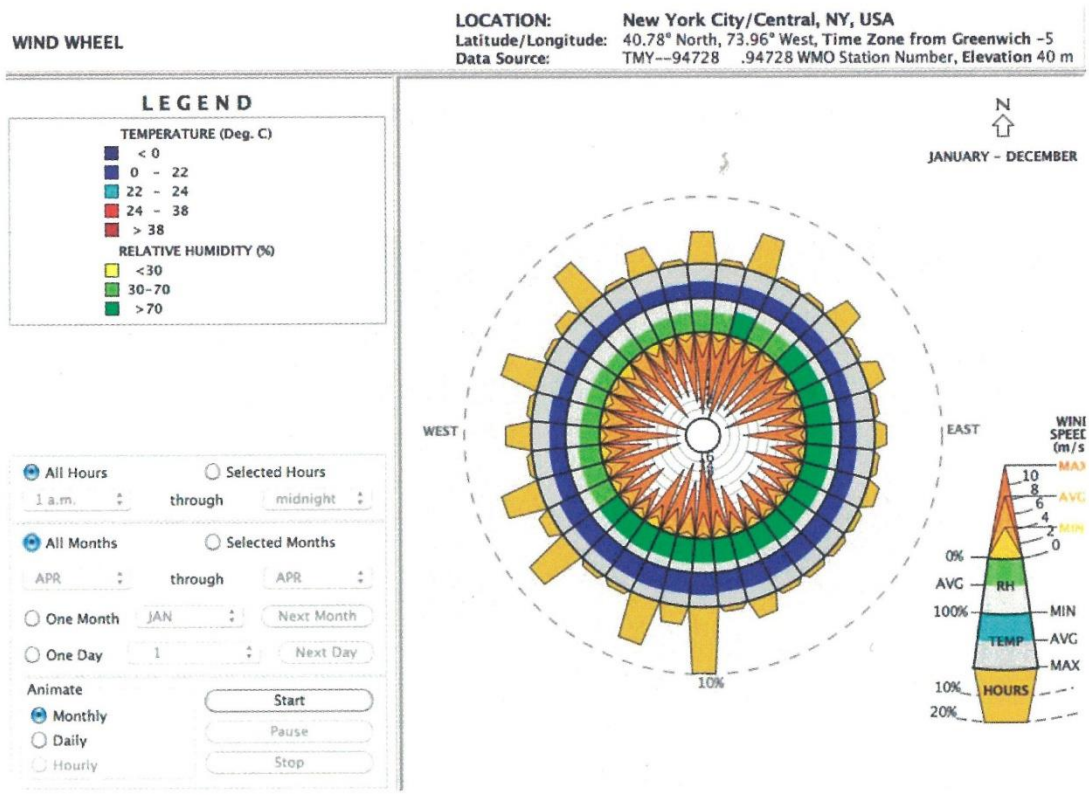

Fig. 284 Wind Flow Data for the Study Area

Figure 285 graphically portrays the results of the wind simulation in plan view at 1.5 meters above the ground level, or pedestrian level. It indicates slower wind speeds primarily on the north-west side of the study area, with some obvious shadowing from dense blocks of mid-rise buildings and relatively narrow streets. Open spaces have relatively high wind speeds at around 3 meters/second.

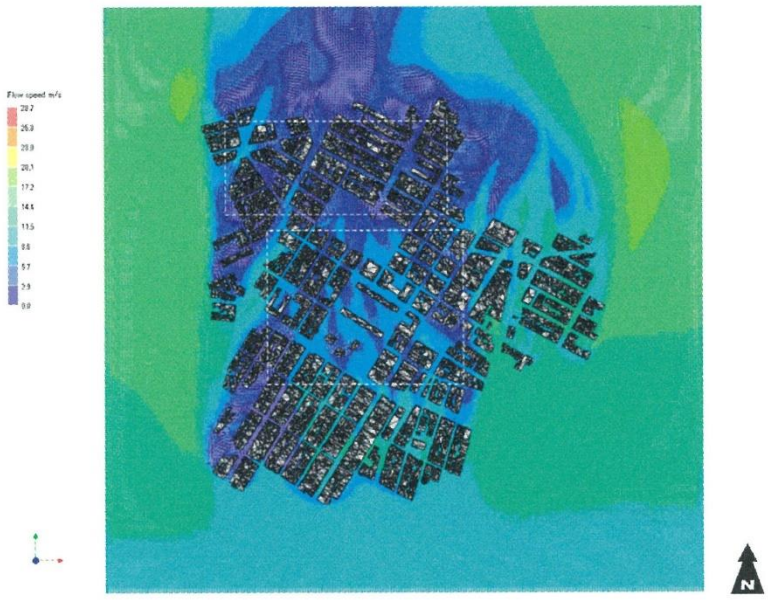

Fig. 285 Plan View of Wind Flow

Figure 286 depicts wind flow running along a section of the three-dimensional block model as a line of relatively laminar flow rising in velocity with height.

Figure 287 shows a similar result, but also with distinct perturbations of wind flow associated with taller buildings in the study area.

Figure 288 portrays patterns of wind flow through the study area and at varying elevations. By and large, the study area appears to be relatively sheltered with the exception of some gustier areas.

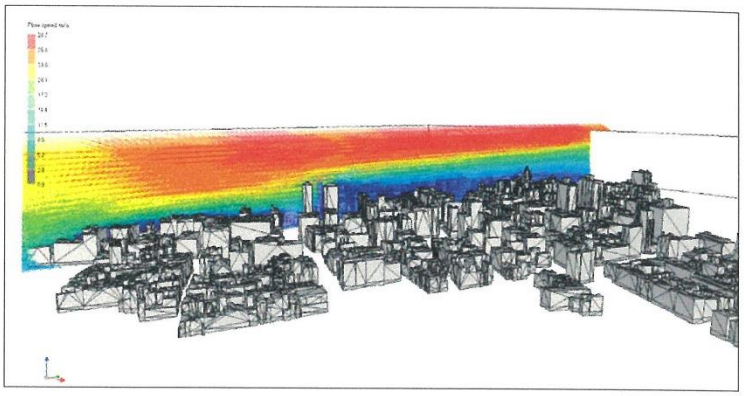

Fig. 286 Oblique View of a Shard of Wind Flow

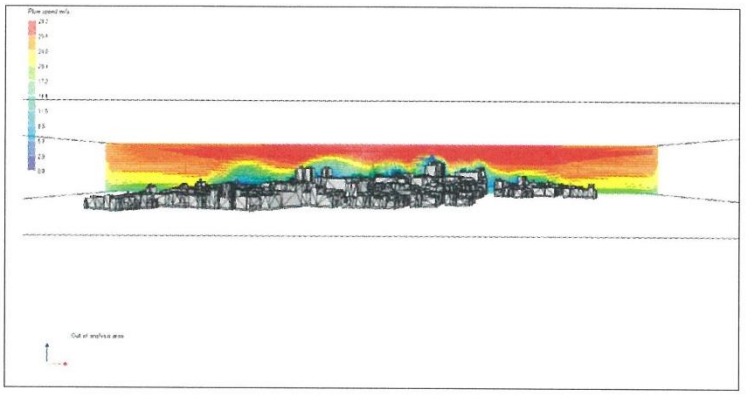

Fig. 287 Section View of Wind Flow

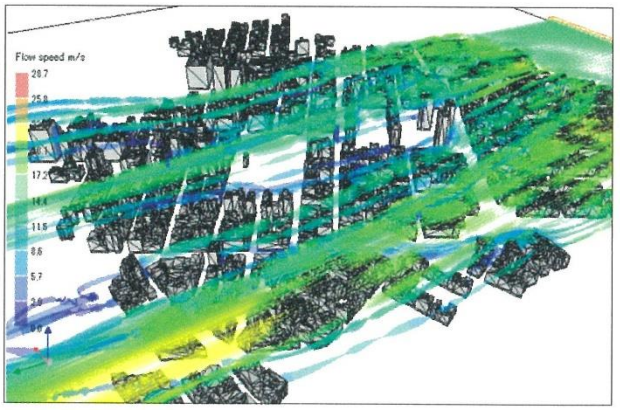

Fig. 288 Composite View of Wind Flow

Figures 289 and 290 depict aspects of the shady area in Chuo-ku in central Tokyo. The study site is located on an island in Tokyo harbor known as Tsukishima. It is one of the remaining remnants of the lower city or Shitamachi occupied by commoners during the Edo period. Much of the older city fabric has been conserved, although several larger and taller buildings have also been constructed in the area as shown.

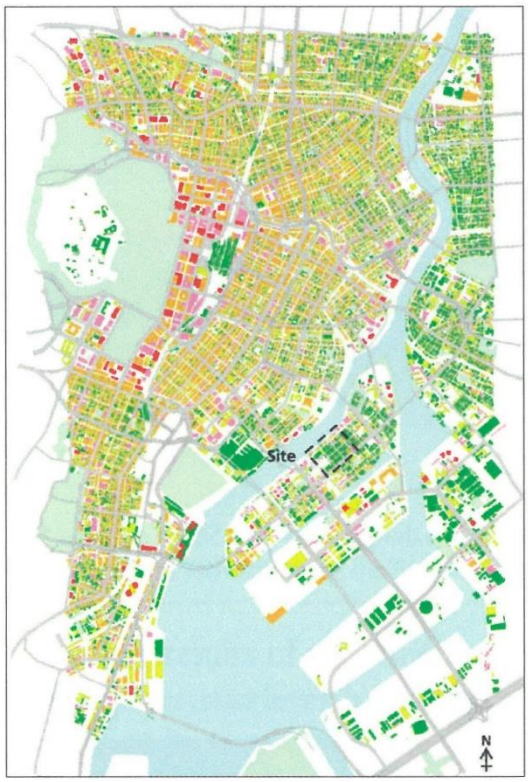

Fig. 289 Study Area in the Context of Chuo-ku

Fig. 290 Tsukishima Study Area

Figures 291 and 292 depict the three-dimensional building and block model of the study site and the plan layout of lots, building blocks and streets, respectively. Regular blocks measure on the order of 120 meters by 60 meters.

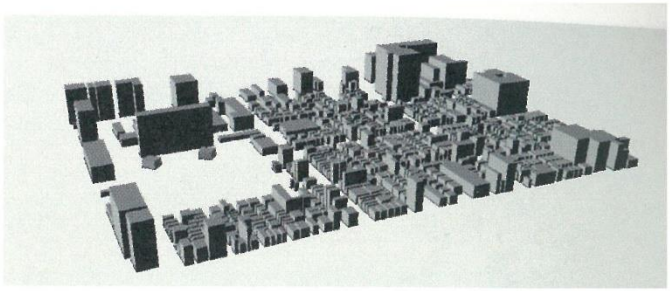

Fig. 291 Three-Dimensional Block Model of the Study Site

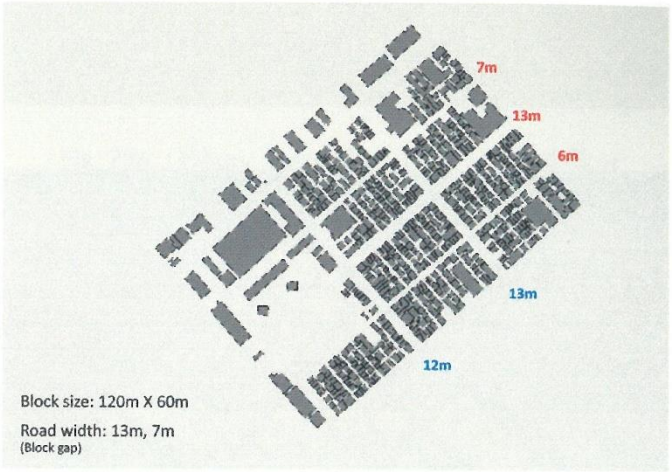

Fig. 292 Plan View of the Tsukishima Study Area

Figure 293 depicts climatic data for the study area in central Tokyo with wind flows during January and December prevailing from the north and north-east. Again, average wind speeds at 35-meter elevation are around 8 meters/second.

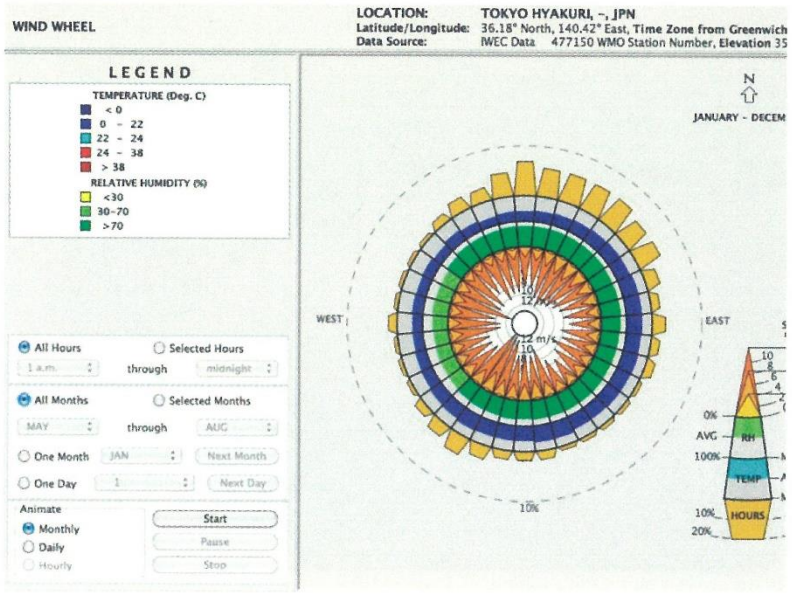

Fig. 293 Climatic Data for the Tokyo Study Area

Figure 294 depicts wind flow in plan view across the site at 1.5 meters above ground or at pedestrian level. It clearly shows that the denser block areas of Tsukishima are well-sheltered, whereas the more open areas and those along the edges of the island are less well-sheltered.

Figure 295 depicts wind flow at 30 meters above the ground, again in plan view. It clearly shows the perturbation and shadow cast by the taller buildings, as well as higher winds in the north-east.

Figure 296 depicts a section of wind flow obliquely through the study area building volumes. It also depicts some apparent acceleration in the vicinity of some of the taller buildings, again coming from the north-east. The low-rise blocks also appear to have little impact on the wind patterns.

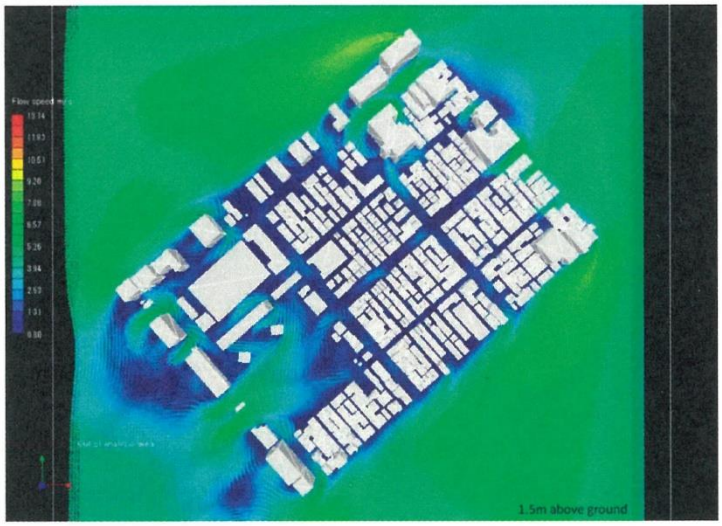

Fig. 294 Plan View of Wind Flow at 1.5 meters

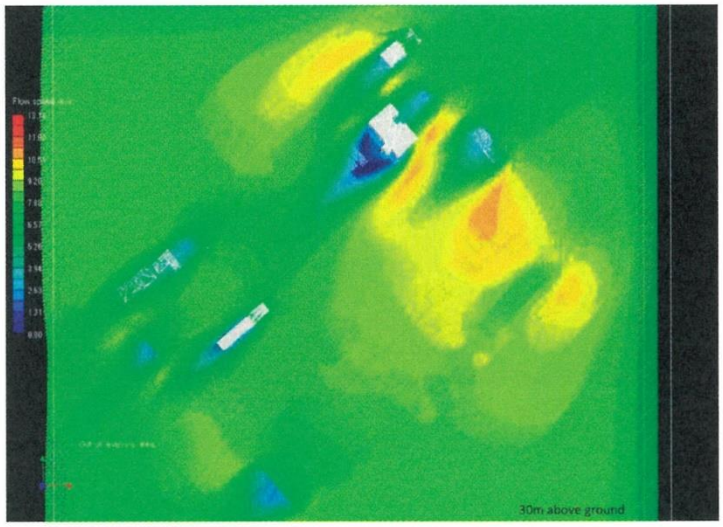

Fig. 295 Plan View of Wind Flow at 30 meters

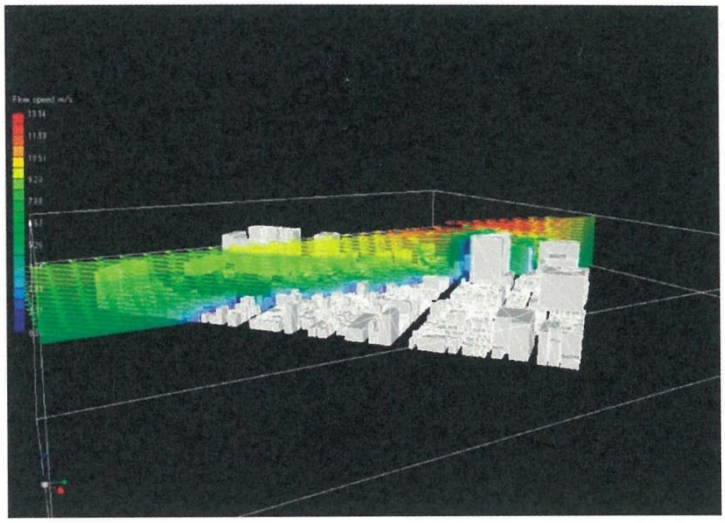

Fig. 296 Oblique View of a Section of Wind Flow

Figures 297 and 298 depict the study area in the CBD of Beijing and in particular the Jianwai SOHO study site. As can be seen, this complex sits astride several large (super) blocks that are surrounded by wide roads. Also, the tall 30-storey buildings of the complex are more sparsely set out than the other earlier examples. Main roads are up to 40 meters wide.

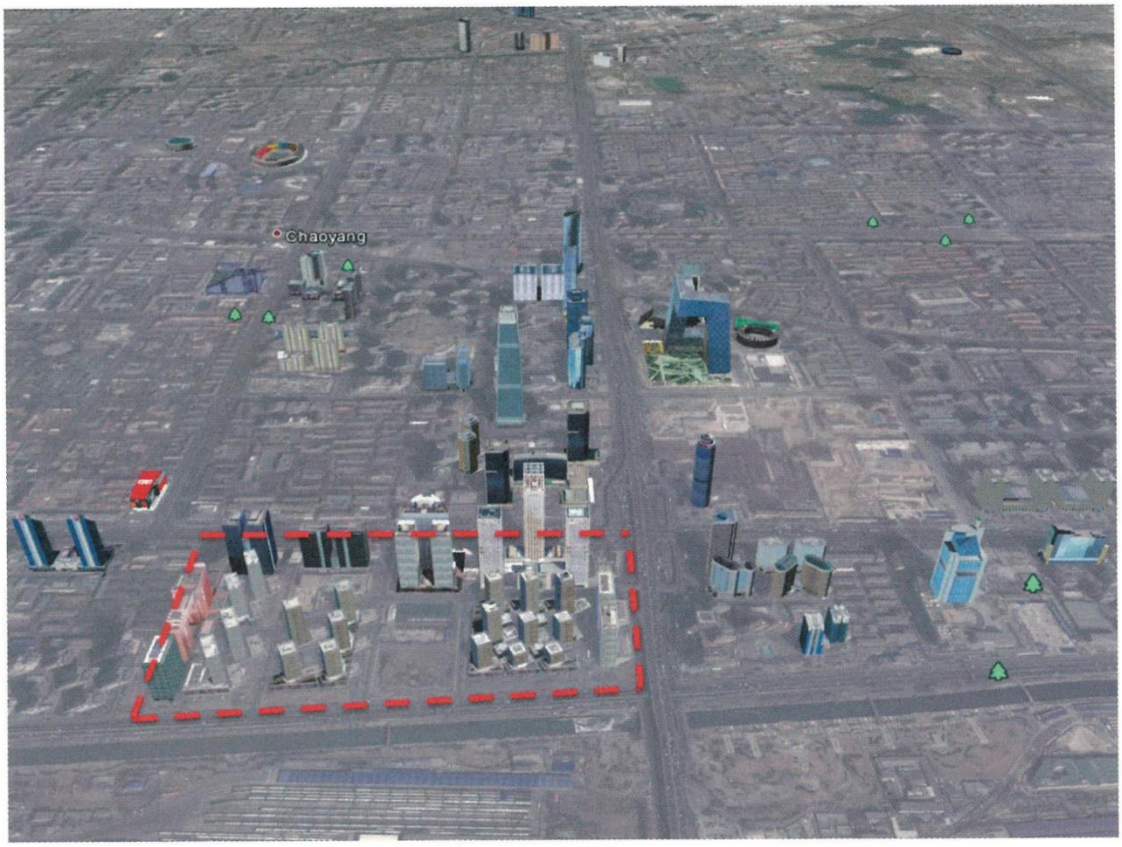

Fig. 297 Study Area Within the Beijing CBD

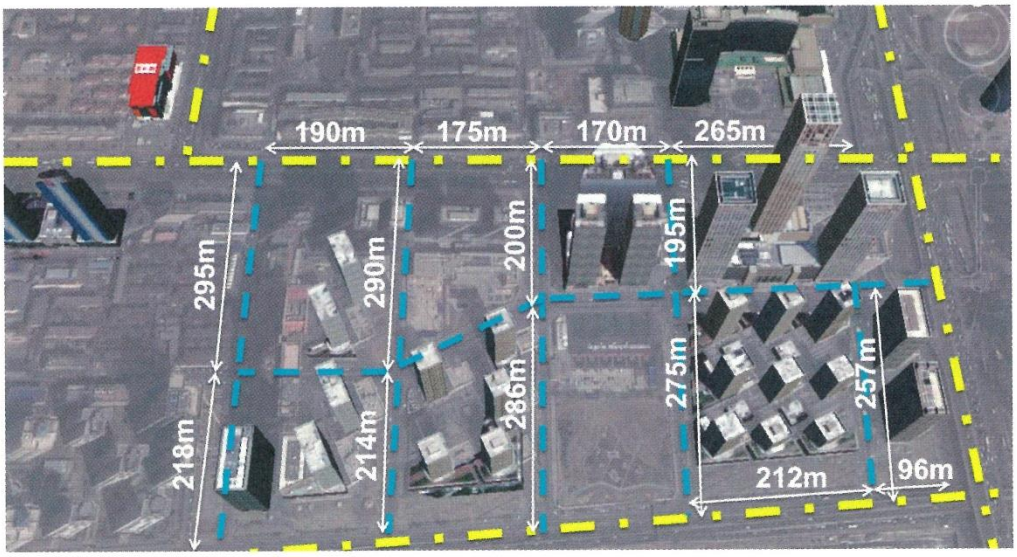

Fig. 298 Jianwai SOHO Complex

Figure 299 depicts the Jianwai SOHO project in relationship to other taller buildings in the nearby vicinity, which would undoubtedly have a significant effect on certain patterns of wind flow. Hence, they were included in the simulation.

Figure 300 depicts the Rhino-based three-dimensional model of the study area complex in selected taller adjacent buildings included in the simulation.

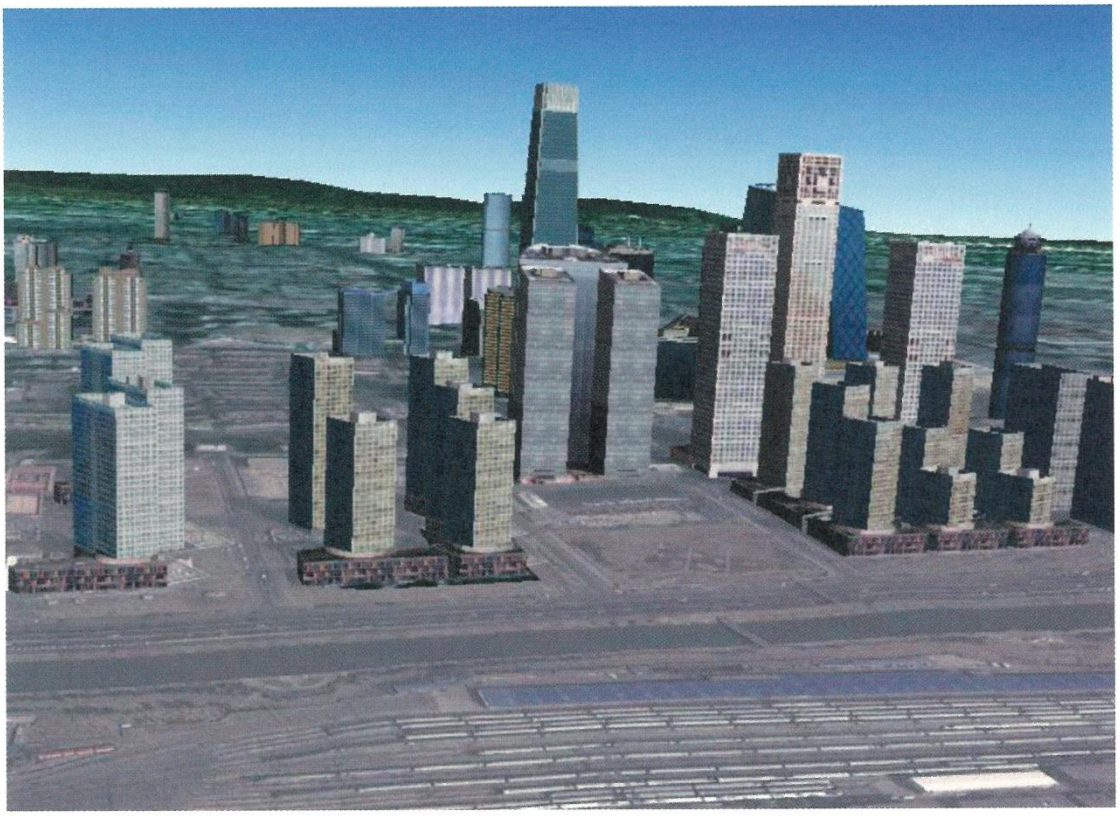

Fig. 299 Study Area and Adjacent Buildings

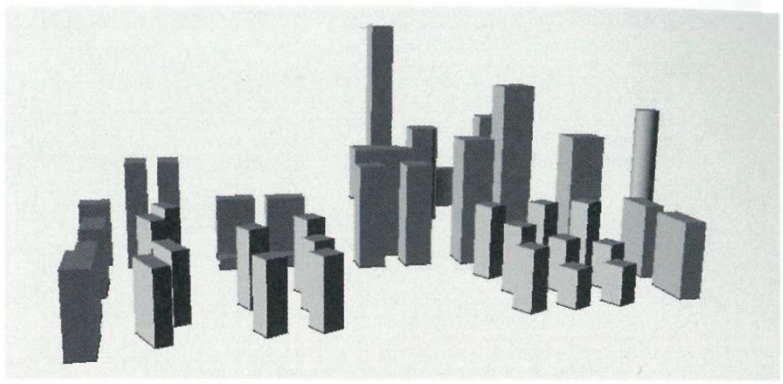

Fig. 300 Three-Dimensional Model of Building Complex and Adjacent Buildings

Figure 301 depicts climatic data for the study area environs in the CBD of Beijing, this time for the summer period of June through August when cooling winds are desirable, together with the evacuation of air pollutants. Dominant winds are in a southeasterly direction with speeds of 8 meters/second at 31 meters.

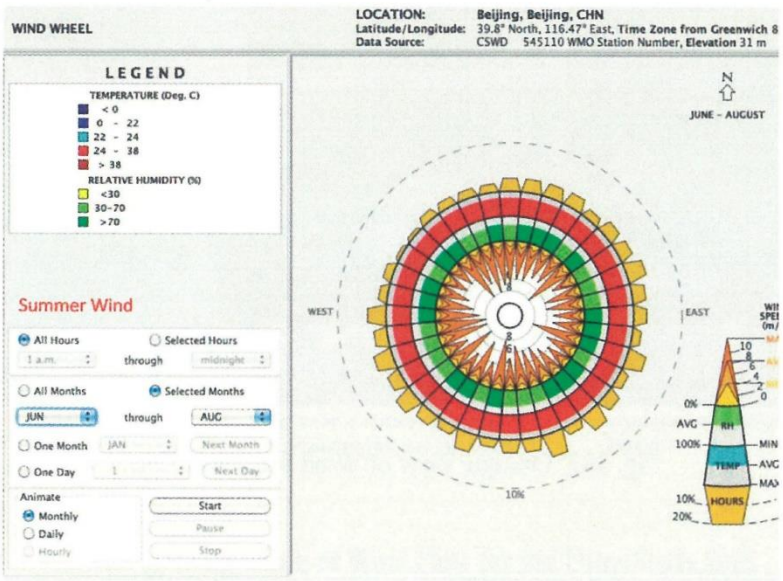

Fig. 301 Climatic Data for the Beijing Study Area

Figure 302 shows the pattern of wind flow in plan form, 1.5 meters above the ground, or at pedestrian level again. The arrows in the depiction clearly show that wind, although not at high velocity, does penetrate into the site and around buildings.

Figure 303 shows a section of wind flow adjacent to the site, also clearly showing the perturbations caused by the taller buildings, probably with significant stream flow and eddy effects, although the wide distance between buildings diminishes these effects.

Figure 304 revisits the plan view of air flow at the pedestrian level, nothing several areas of very low speed flow and even static areas around long-block buildings. Otherwise, the study site is well ventilated.

Fig. 302 Plan View of Wind Flow at Study Area

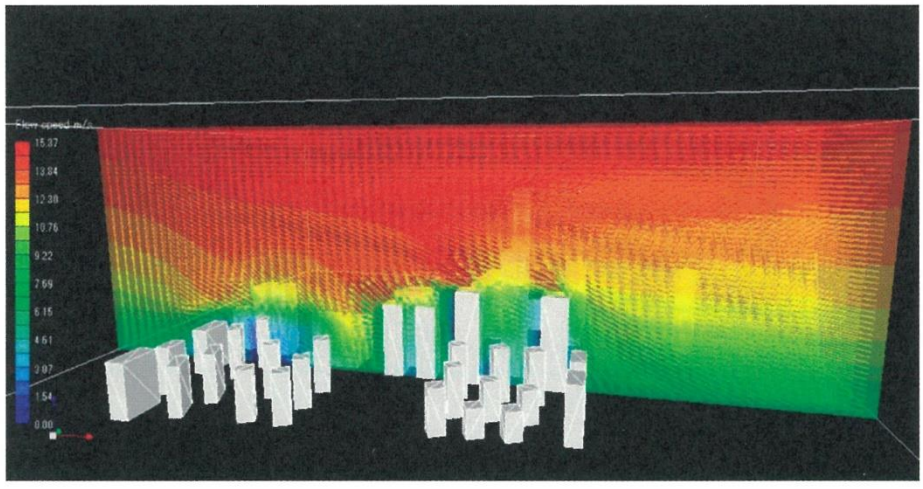

Fig. 303 Oblique View of Wind Sectional Flow

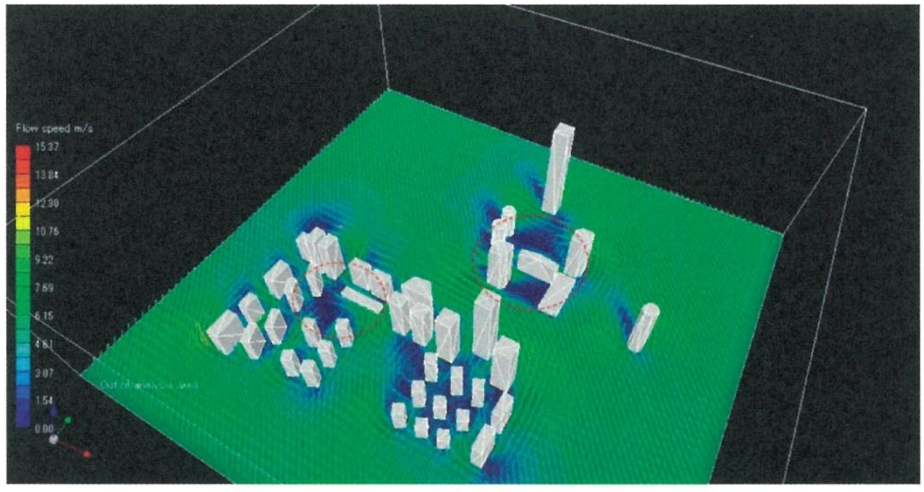

Fig. 304 Low Wind and Static Areas Within the Study Site

Figure 305 presents a brief summary comparison of the three case studies in the wind flow simulation. Both the Manhattan and Tsukishima sites appear to be well-sheltered, at least from the winter winds in the simulation. The Beijing CBD site, by contrast, is quite porous with high wind speeds, all of which is advantageous during the summer months depicted in this simulation. More generally, street spaces between high-rise buildings in small blocks are well-sheltered but less ventilated. This also may become a source of increased energy use and decreased outdoor thermal comfort in summer months. Open spaces among small blocks appears to promote natural ventilation by introducing wind streams into blocks. However, prudent shaping of the open space may be necessary to mitigate the outlet effects at high speed.

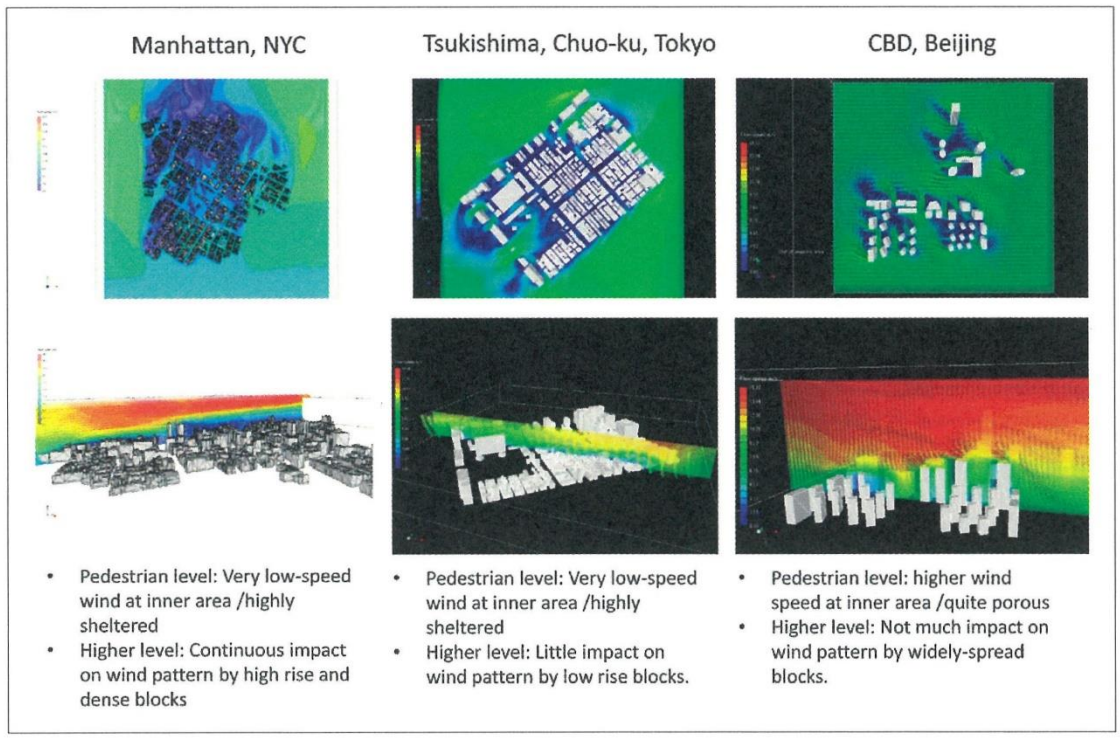

Fig. 305 A Comparison of Wind Flow for the Three Study Sites

(ii) Operational Energy Use

Figure 306 outlines a template of building properties for the modeling of operational energy use, which is defined as the overall energy use intensity (EUI) of a neighborhood. This is given by the energy use of N buildings ≠ N x energy use of one building, because of the effect of the urban microclimate caused by shading of neighborhood buildings, urban heat island, and localized wind patterns, etc. UMI used here mainly considers the shading effect among neighborhood buildings in terms of microclimate, alongside the functions and properties of every building and the climate of the city. The building properties in this example are: Ashrae 90.1 Zone 5A with an office schedule and heavy activity.