Wind Study

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IN PARTNERSHIP WITH R.L.ENGEBRETSON.

INTRODUCTION

Wind and snow are two factors which have the ability to heavily impact a building. Understanding how these forces act upon and interact with the building and site help designers respond to the conditions and prevent unnecessary damage. Through the use of computer simulations, real-world weather situations are able to be imitated and the responses analyzed, without the need for them to actually occur.

While analysis of buildings can be done prior to construction for the prevention of possible problems, other unexpected issues may arise upon the completion of a project. Simulation scenarios allow for existing problems to be studied and for solutions to be found, as occurred with this research project.

"To achieve this end, the designer needs information regarding (1) the wind environment, (2) the relation between that environment and the forces it induces on structure, and (3) the behavior of the structure under the action of these forces" (Wind Effects on Structures, 1).

BACKGROUND INFO

This project examines questions regarding wind pressure on roofs, around a building site, and in entry vestibules. The problems that arose consisted of high pressure areas on the roof, snow drifts developing in undesirable locations, and interior ceiling tiles in the vestibule blowing out of their tracks because of high wind pressure. The simulations performed sought to determine the location and amount of the highest wind pressure exerted on the roof's surface as well as in the vestibule. This study also analyzed the impact that the inclusion of an outlet had for the wind flow to exit through. In addition to these, how wind acted with the building and site conditions was studied to determine how snow interacted with the building, external elements, and the site due to wind. Simulation software is able to replicate these conditions for the determination of the results.

“Accordingly, it has become necessary to develop tools enabling the designer to estimate wind effects with a higher degree of refinement than was previously required” (Wind Effects on Structures, 1).

Using site specific information, Autodesk computer software is able to determine how wind interacts with different parts of the building. The program Flow Design allows pressure on the building surfaces to be viewed and measured. Vasari shows wind interaction with the building and site as well as flow patterns. Simulation CFD is also a useful tool in the analysis of wind behavior. Its ability to show wind flow patterns in interior spaces, as well as the applied pressure on those surfaces, allows it to depict the changing conditions that occur in an entry. These programs influence the type of framework being used for the completion of the project.

The philosophical framework for this research involves mimesis, which is the replication or imitation of actual events. Through this process of replicating real-world objects and settings, an understanding can be gained of how wind pressure affects the built environment. Analysis of these results allows future design decisions to respond to the information in order to create a more successful design strategy.

The methods used in this research framework are quantitative and deductive, because it depends on changing phenomena that is measured with numbers, and is based on cause and effect. In the study, a specified velocity of wind is directed toward the model, and the resulting conditions help provide alternative solutions that could improve building performance. The conceptual framework also follows the positivist tradition because the information used can be objectively measured, and is assumed to reflect reality.

PROCEDURE

Simulation research involves replications of reality. However, many of these envisioned realities do not currently exist in the real world. The use of this research method allows a safe, effective way to analyze data. Thoroughly understanding all of the programs used allows them to be utilized fully and in conjunction with each other. These computer programs are able to analyze complex situations based on the given parameters and determine the results, which allowed for the completion of this project.

The procedure used for this research project included several steps. To begin, a meeting with the sponsoring firm occurred for the clarification of the project statement and to confirm what they hoped to gain from the research project. Before any software was used, background research was conducted. A thorough literature review was completed in order to more completely understand the topic and existing solutions to the various problems. During further information gathering, appropriate research methods to be used were identified, as well as different techniques and tools. Various tutorials and articles were watched and read to learn how to best use the unfamiliar software.

As the project progressed, the main work on the design research began. This was split into three primary sections, including wind pressure on the roof and skylights, around the building site, and in the entry vestibule. During this time, progress meetings were scheduled with the firm to discuss preliminary results and to determine what should be changed or modified in order to present the final results in the most clear and precise way possible. Most importantly, this included ensuring that the proper units were used for easy understanding.

To conclude the project, the final documentation and report was prepared for the presentation of the findings to the firm. Collecting the results and combining the information together allows a more complete understanding of how wind acts on all aspects of a building, including the exterior, interior and on the surroundings.

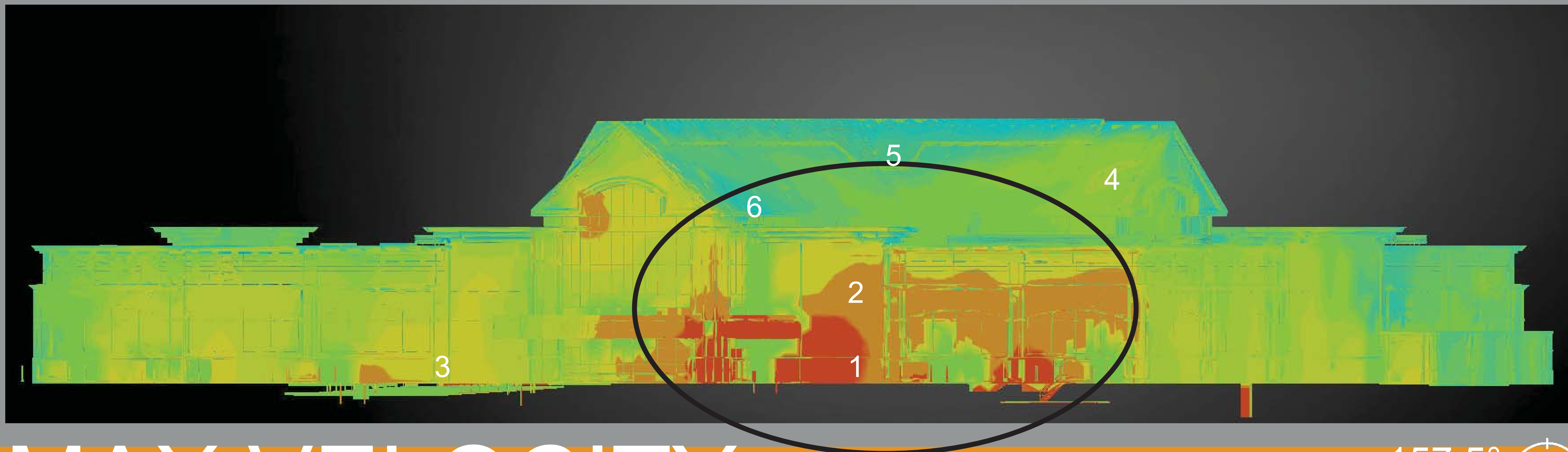
In order to begin the research process, a three-dimensional model is needed. Revit is a building information modeling design software that allows users to accurately model a building in detail. It is able to easily accept changes to the elements in a 3D model by propagation. It is also able to incorporate time, making the software 4D. The program is able to create realistic renderings, contain construction information, and perform energy analysis specific to a site. It is also compatible with most other Autodesk programs. Initially starting with a Revit model allows the process of using the various programs to become much smoother, as all the programs are connected. By exporting the model to the other programs through different formats, and then choosing to import it within those programs, the simulation process may begin.

"The pressure distribution on building walls is influenced by a wide range of factors including approach-flow conditions, urban surroundings, building geometry and wind direction" (CFD simulation of wind-induced pressure coefficients on buildings with and without balconies, 1).

skylight wind pressure study

This portion of the research project involved studying the wind pressure distribution on the sloped roof and skylights in order to determine what wind loads the structure should be designed for by using the maximum and most frequent wind conditions. The program which was determined to work best for this analysis was Autodesk Flow Design. This program consists of a wind tunnel which models air flow around a building and site. Unlike other programs, it allows the visualization of the varying pressure distribution on a building. It can be customized in order to replicate actual conditions by allowing the direction and wind speed to be set.

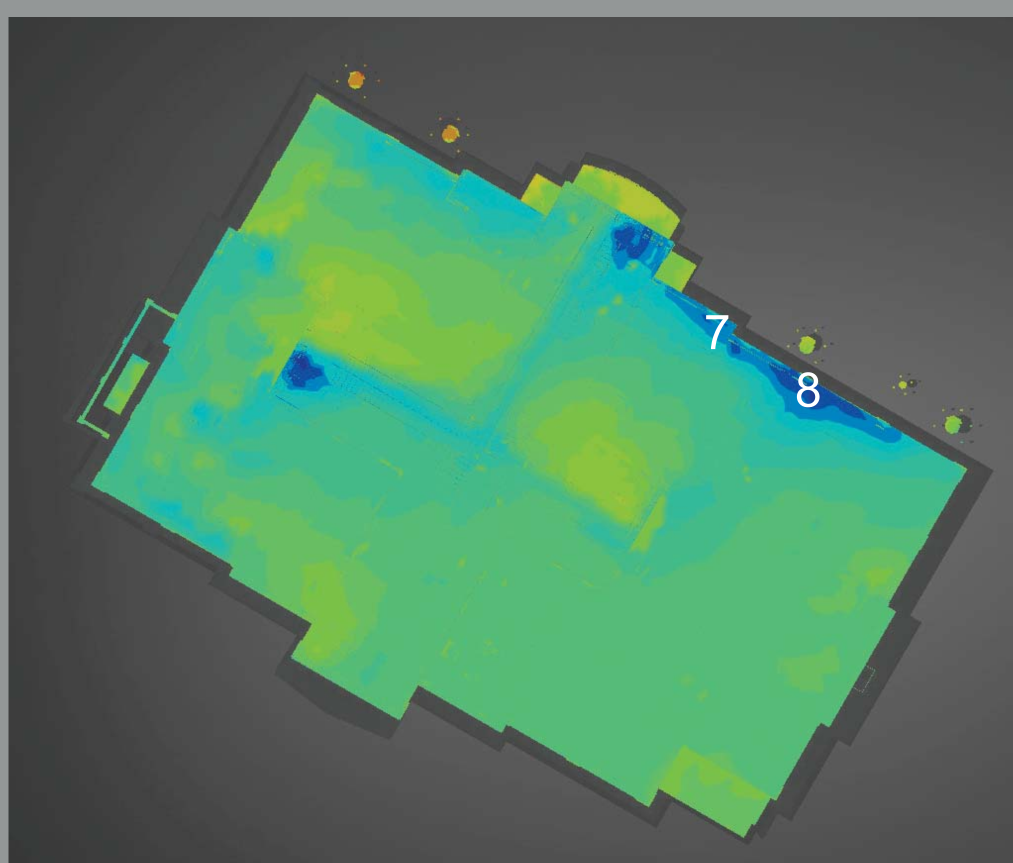
After importing the model into Flow Design, the orientation must be set according to the direction that the wind will be from. This allows for the observation of the wind flow vectors as they flow around the building. By using the correct wind conditions that occur at the site, the actual pressure that acts on the building can be observed through the use of different colors. Different options can be chosen to view the results more clearly. These include banding and contours, which more clearly define and separate the areas of impact. Other factors which need to be considered when using this program are ensuring that the proper units are being used for wind velocity and building size. The colored gradients showing the wind pressure can be further analyzed through Adobe Photoshop in order to create exact matches between the given numerical unit and the color on the model. These results depict where the maximum pressure is present on the building. This allows for appropriate strengthening of the building to occur where needed in order to have appropriate load strength.

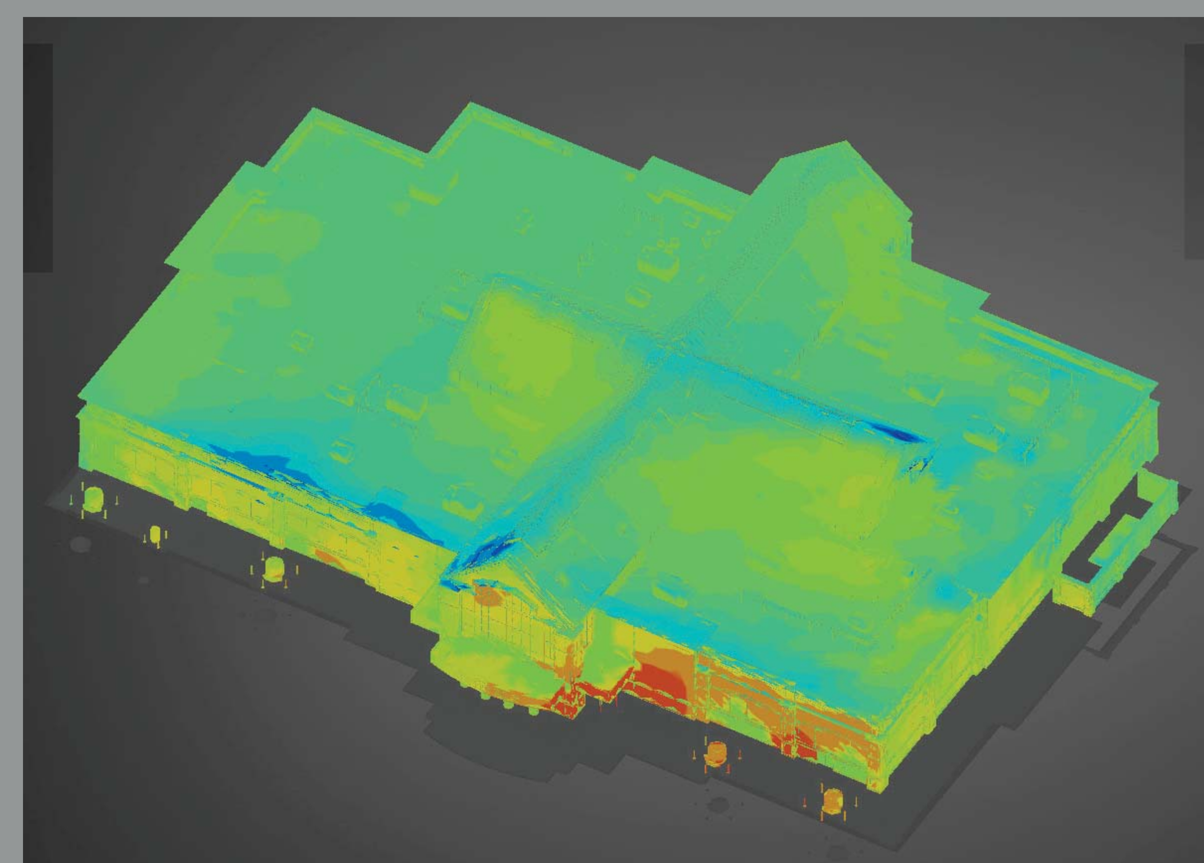


1 5.5 lb/ft^2
2 4.7 lb/ft^2
3 2.9 lb/ft^2
4 1.2 lb/ft^2
5 -1.5 lb/ft^2
6 -2.7 lb/ft^2
7 -7.0 lb/ft^2
8 -8.6 lb/ft^2

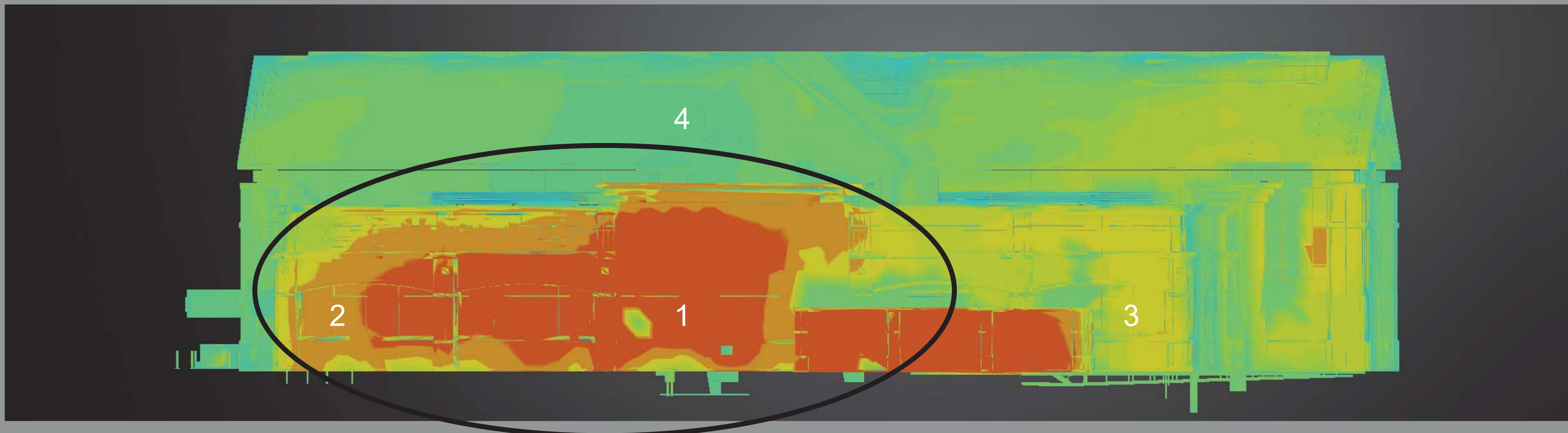
MAX VELOCITY

157.5°
68.35 ft/s





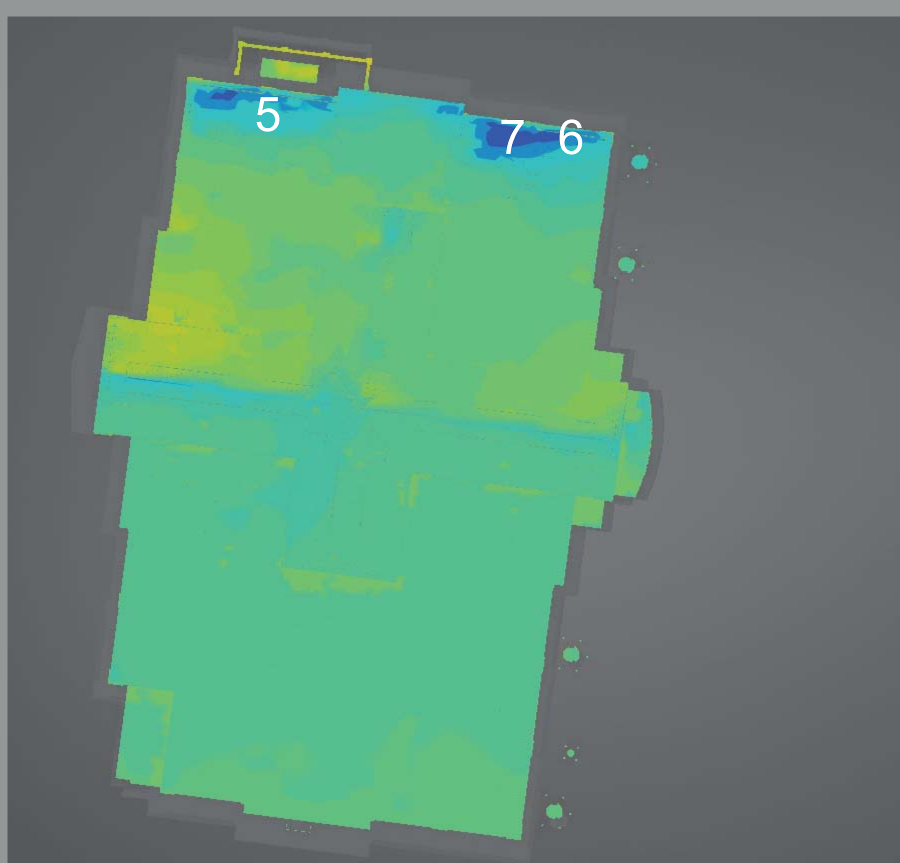
From the results found from studying the wind loads on the roof and skylight, the areas of highest pressure can be determined to be on the leading northwest corner. This occurs when the wind has a velocity of 46.6 mph from 67.5 degrees west of north, which occurs during the month of December. This results in maximum pressure areas of 5.45 lb/ft2.

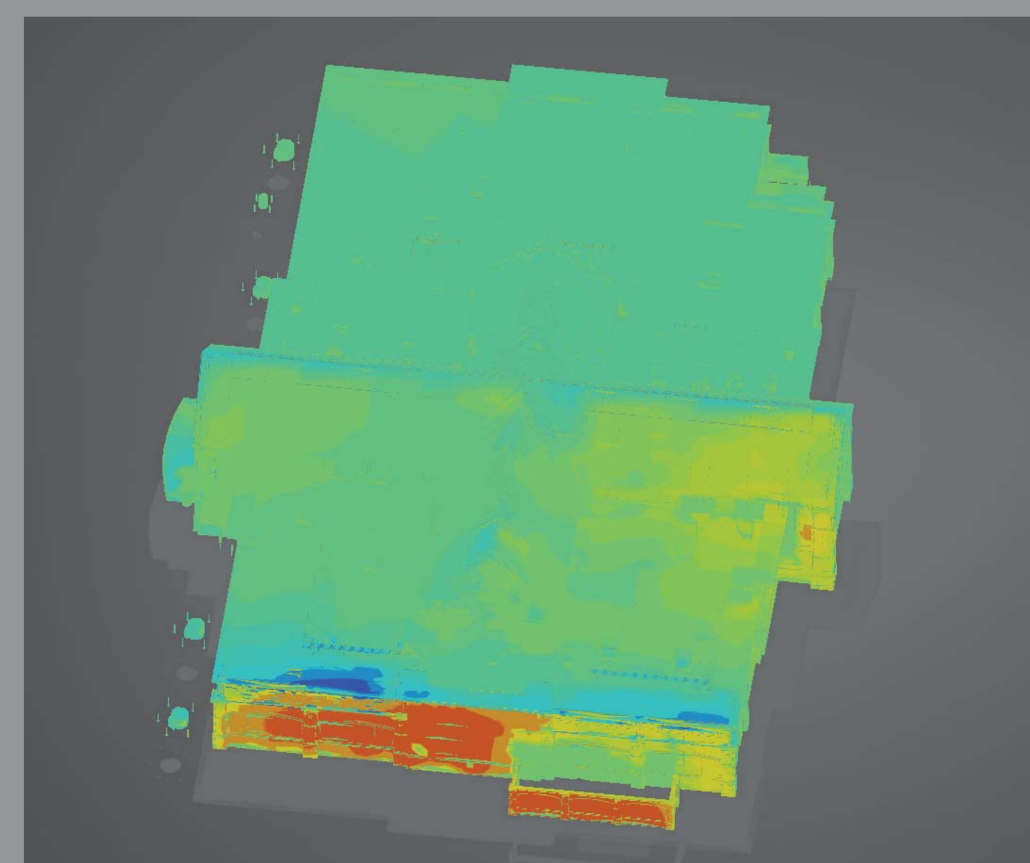


1 0.47 lb/ft²
2 0.39 lb/ft²
3 0.27 lb/ft²
4 -0.05 lb/ft²
5 -0.38 lb/ft²
6 -0.47 lb/ft²
7 -0.57 lb/ft²

MAX FREQUENCY

180°
14.0 mph





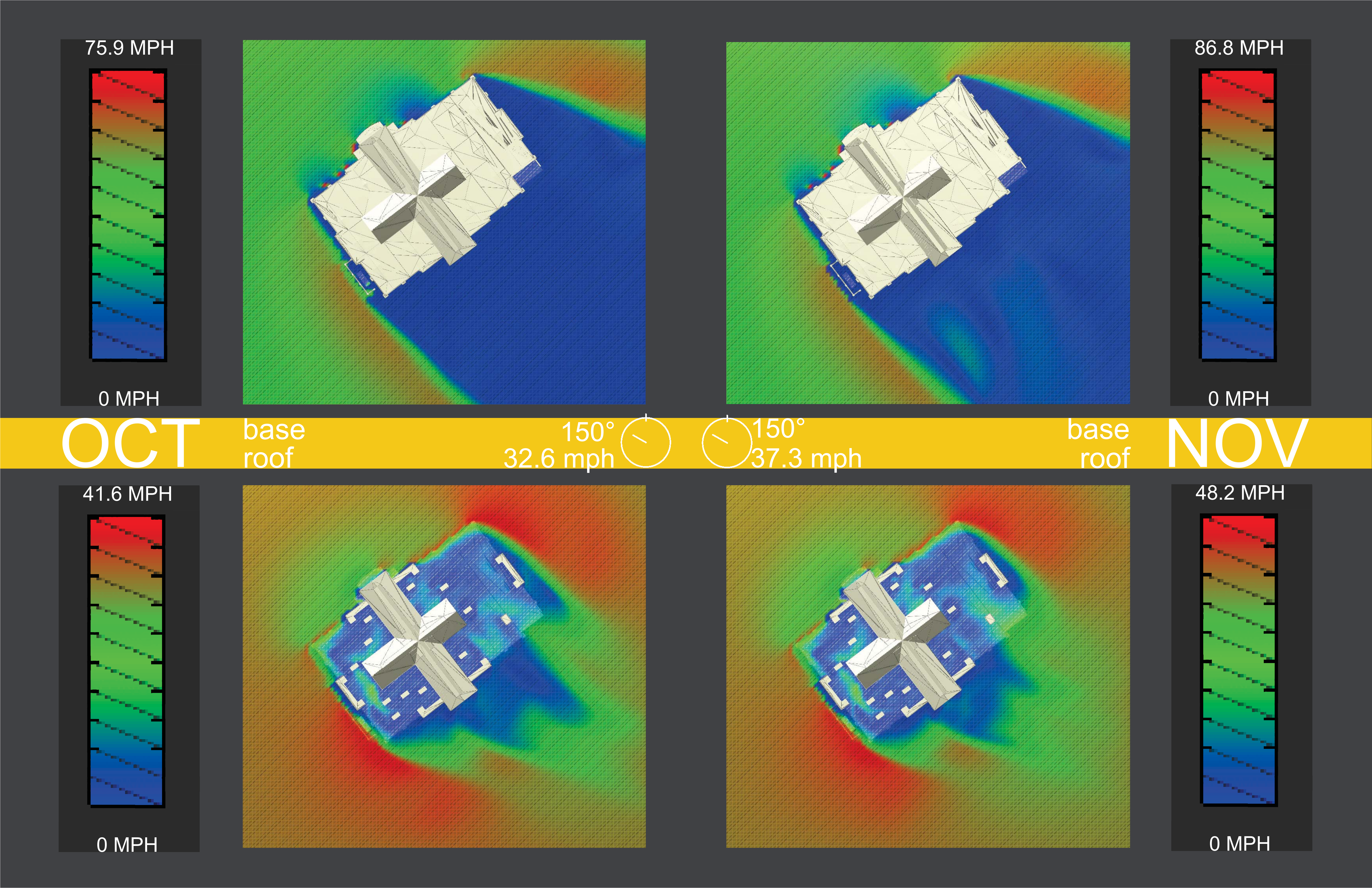
The results from the most frequent wind conditions are much less severe. They blow from the southwest at 14.0 mph resulting in a maximum pressure of 0.47 lb/ft2 on the western face of the building.

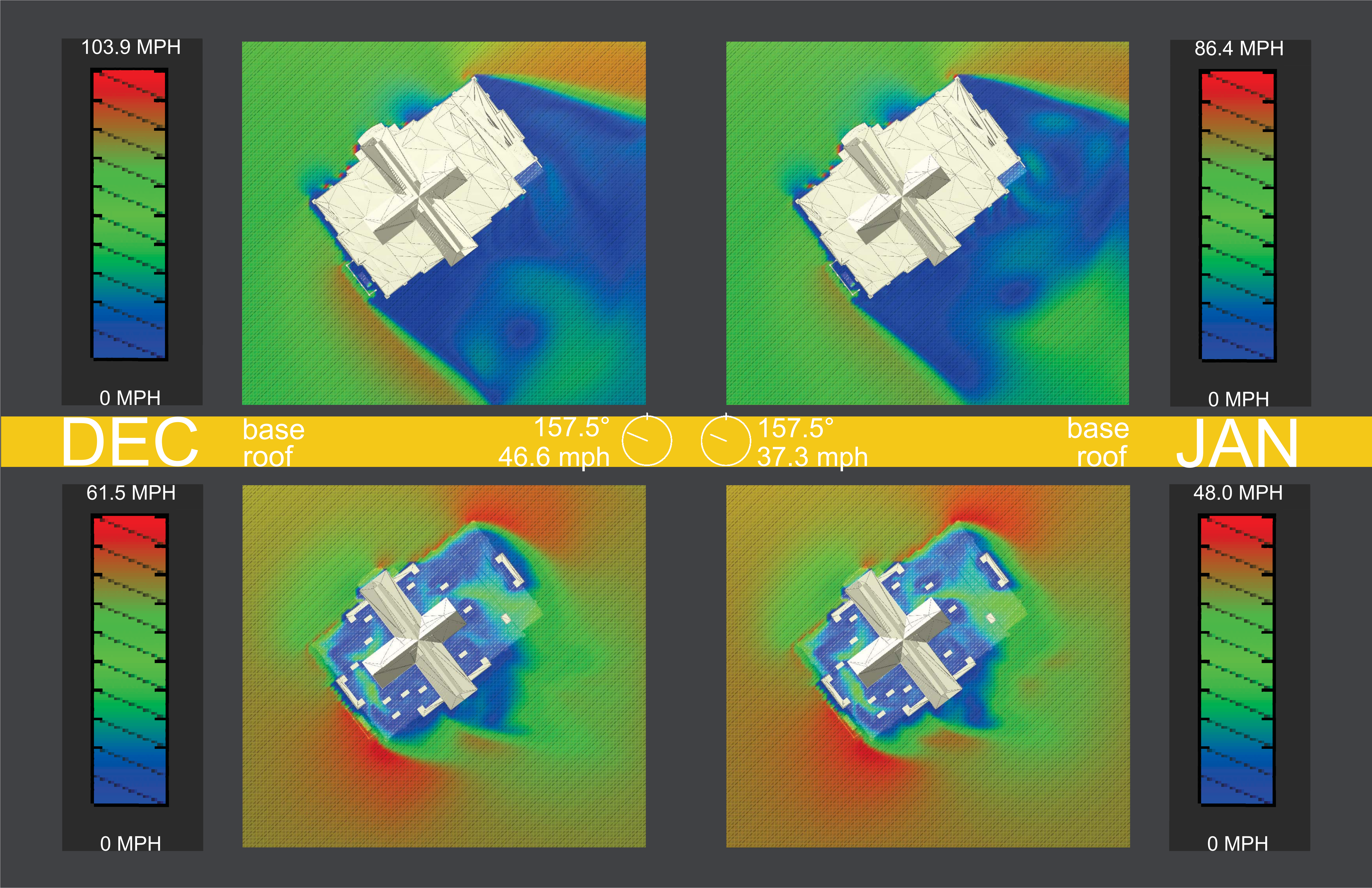
“Wind is air movement relative to the earth, driven by several different forces, especially pressure differences in the atmosphere ... and forces generated by the rotation of the earth” (Wind Loading of Structures, 1).

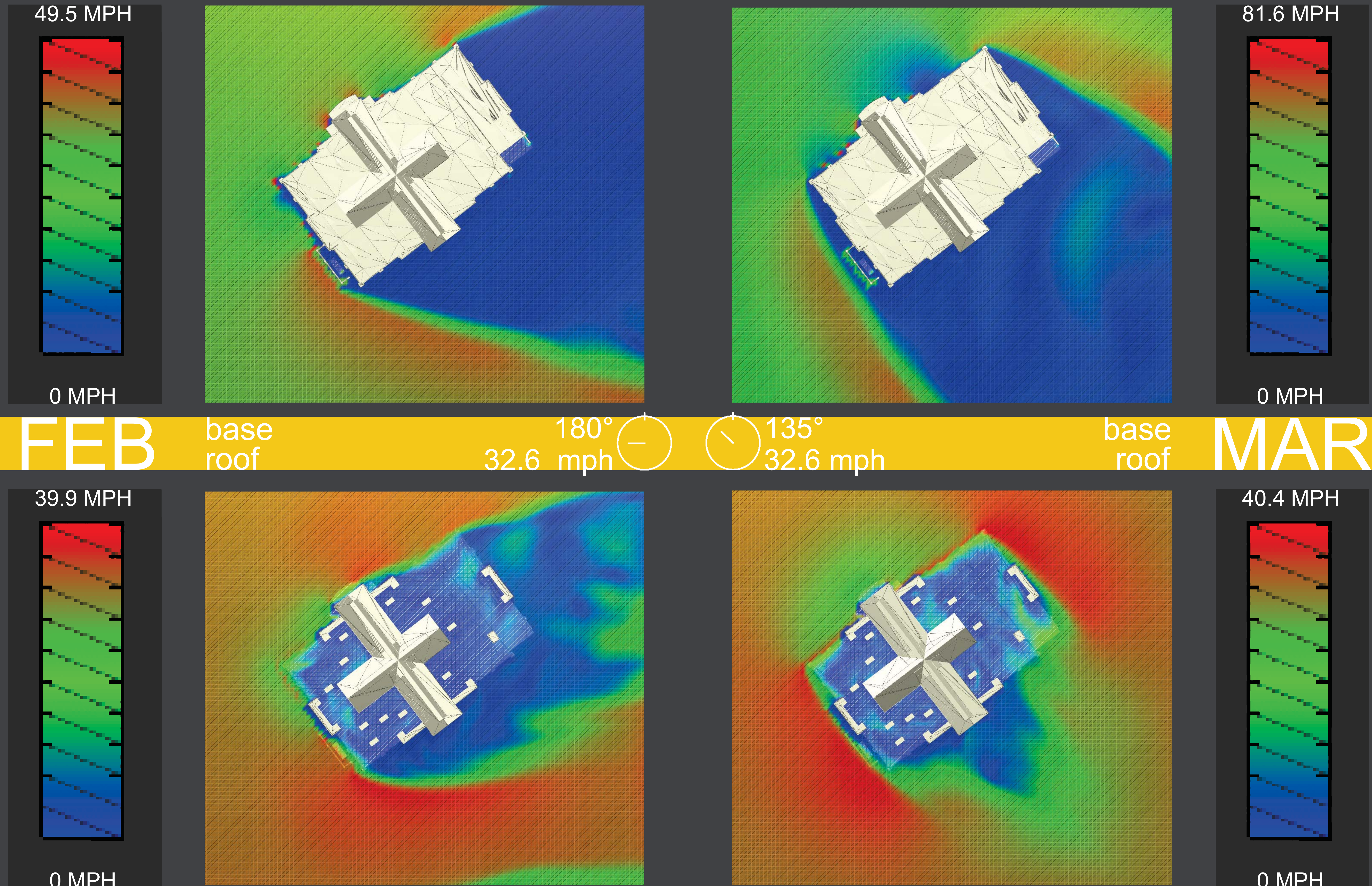
snow drift study

Determining the areas around the building where snow drifts would accumulate is another part of the research study. This only requires simulating the conditions during the winter months of October through May. For this portion, the program Vasari was used. Using the wind tunnel portion of Vasari and specifying the project location enables the creation of wind patterns around a building and surrounding area that replicate actual conditions.

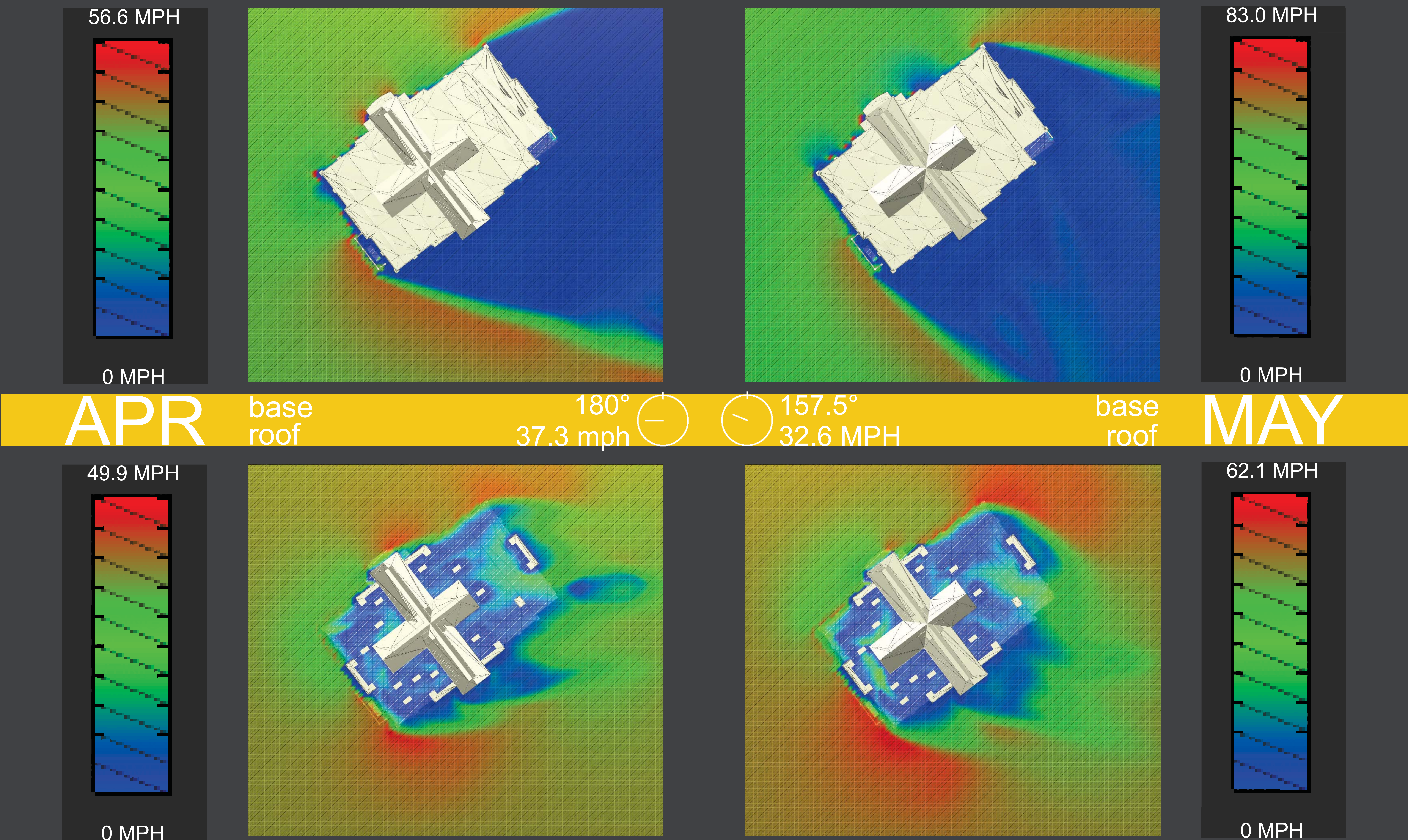
Analyzing the model after bringing it into Vasari provides information about how the building interacts with the environment and how wind patterns and pressures change as a result of it. Including actual data for wind levels and directions into the program parameters permits the information to become site specific. The results of this analysis are shown graphically at both the ground level and roof level, which allows for the determination of where snow drifts will form in the winter months by showing where the strong and weak wind paths are.


75.9 MPH
0 MPH
86.8 MPH
0 MPH
OCT
base
roof
150°
32.6 mph
150°
37.3 mph
base
roof
NOV
41.6 MPH
0 MPH
48.2 MPH
0 MPH


103.9 MPH
0 MPH
86.4 MPH
0 MPH
DEC
base
roof
157.5°
46.6 mph
157.5°
37.3 mph
base
roof
JAN
61.5 MPH
0 MPH
48.0 MPH
0 MPH



49.5 MPH
0 MPH
81.6 MPH
0 MPH
FEB
base
roof
180°
32.6 mph
135°
32.6 mph
base
roof
MAR
39.9 MPH
0 MPH
40.4 MPH
0 MPH


56.6 MPH
0 MPH
83.0 MPH
0 MPH
APR
base
roof
180°
37.3 mph
157.5°
32.6 MPH
base
roof
MAY
49.9 MPH
0 MPH
62.1 MPH
0 MPH

“Knowledge of the pressure distribution on building walls is important for the evaluation of wind laods and natural ventilation” (CFD simulation of wind-induced pressure coefficients on buildings with and without balconies: Validation and sensitivity analysis, 1).

vestibule study

Studying the air pressure on the interior surfaces of the entry vestibule in order to determine wind loads is another part of the overall study. By only simulating the wind directions and velocities that affect the entrance, the results remain accurate. A program that allowed this was analysis was Simulation CFD, which is a computational fluid dynamics software that provides flexible fluid flow analysis.

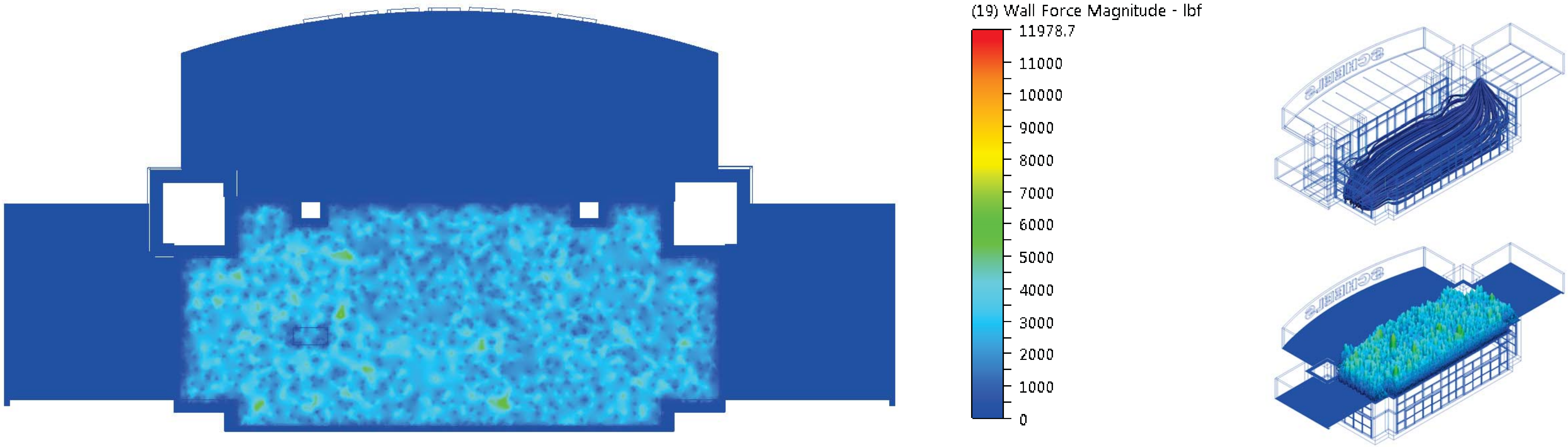
Using Simulation CFD as a design tool produces useful information since it is able to determine the pressure exuded on the surfaces of the building. This program has the capability to launch directly from Revit, and can be customized for each project. The building materials and boundary conditions must be set in order to replicate the actual conditions as closely as possible. In order for the simulation process to begin, the model must first be completely enclosed. This includes eliminating overlapping and structural elements that the walls may contain. Of the wide range of information possible as a result of this simulation, the analysis important for the wind study included interior wind flow patterns and the resulting high pressure areas. To determine visually where these areas occur, the Wall Force Magnitude can be calculated within the program. This shows the varying amounts of forces exerted on the ceiling. In reaction to these areas, vents could be inserted into the ceiling in the area of highest pressure to decrease the total forces acting on it.

The results of this study showed the areas of highest pressure exerted on the interior building surfaces. As the wind speed increased, so did the pressure amounts. In order to determine the wind amount in the direction parallel to the entry doors, the components of the wind direction had to be broken up.

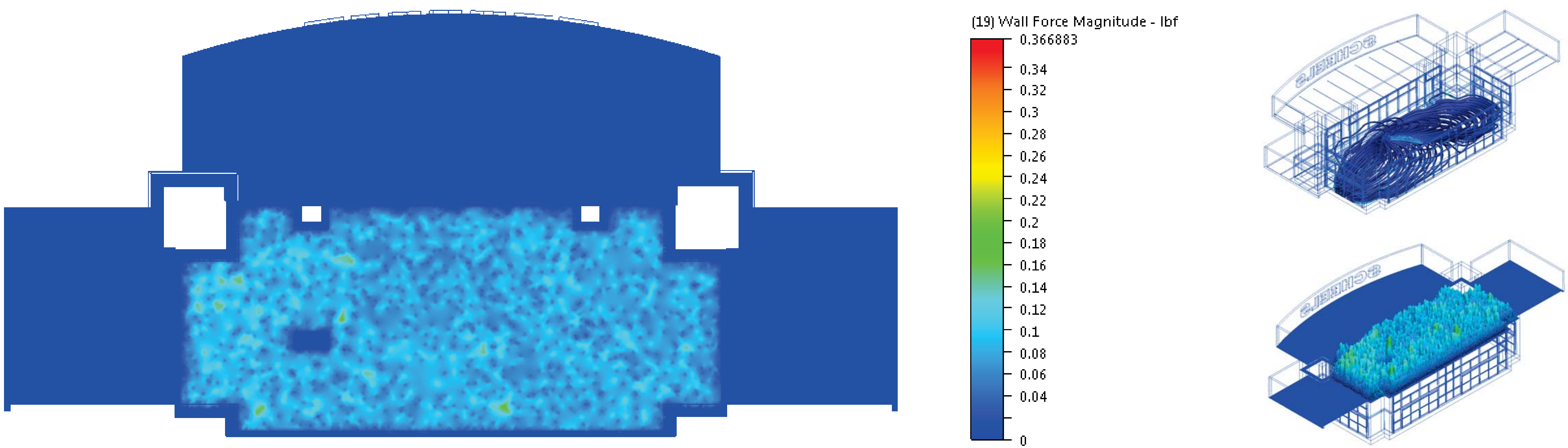
This resulted in the strongest wind occurring from the west during the month of April with a total wind speed of 29.8 mph. When the air flow was compressible, the maximum force exerted on the ceiling in these conditions was 0.6 lbf.

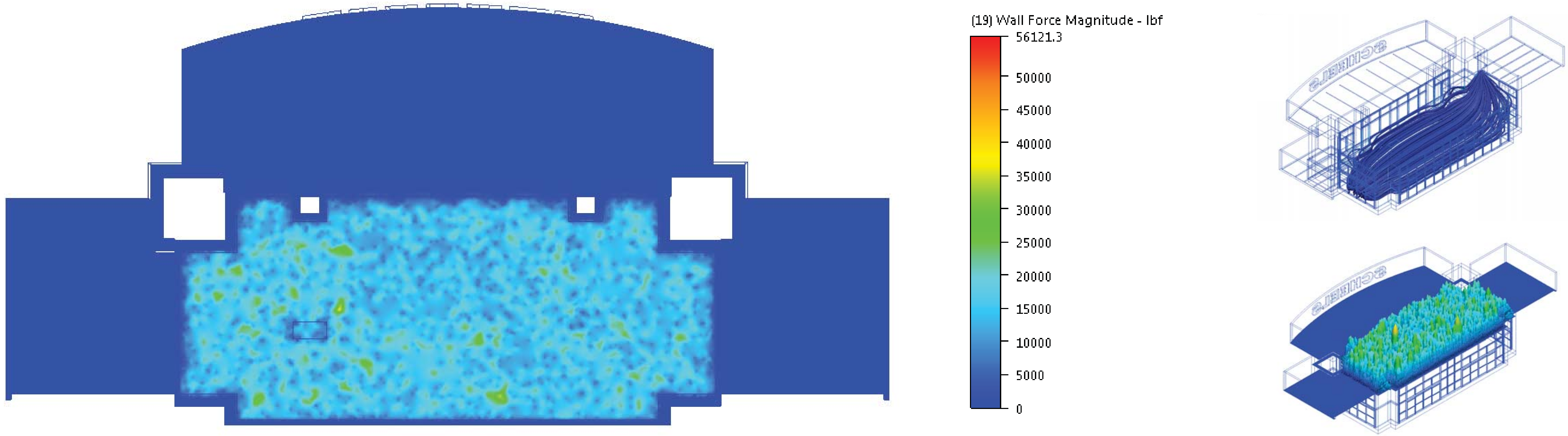
The most frequent wind condition was 13.86 mph from the southwest, which resulted in a force of 0.3 lbf acting on the ceiling when the air flow was compressible.

With all of these results, the location of the different resulting forces remained similar, though the amount of them varied. This allows the exit vent to easily be placed in an area of high pressure.

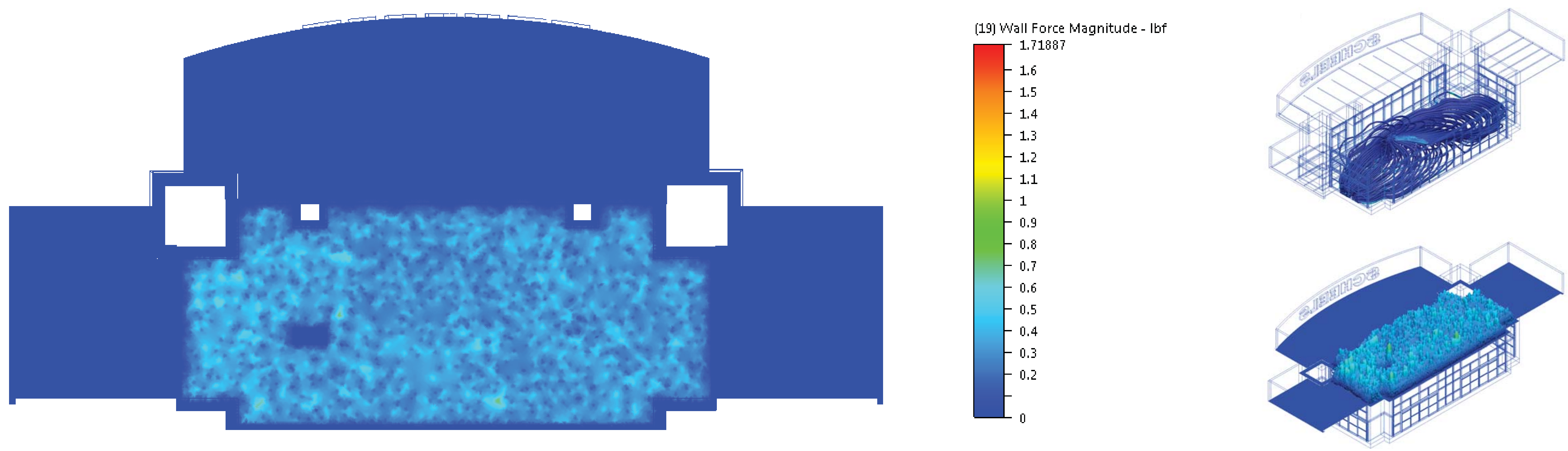


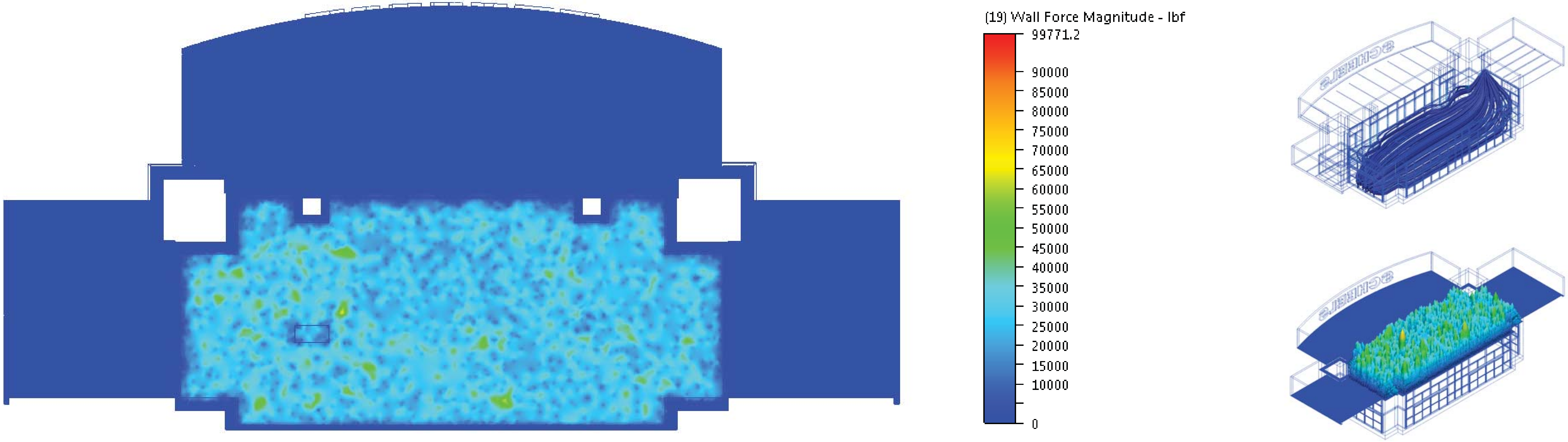
13.86 mph no outlet / outlet — incompressible air flow



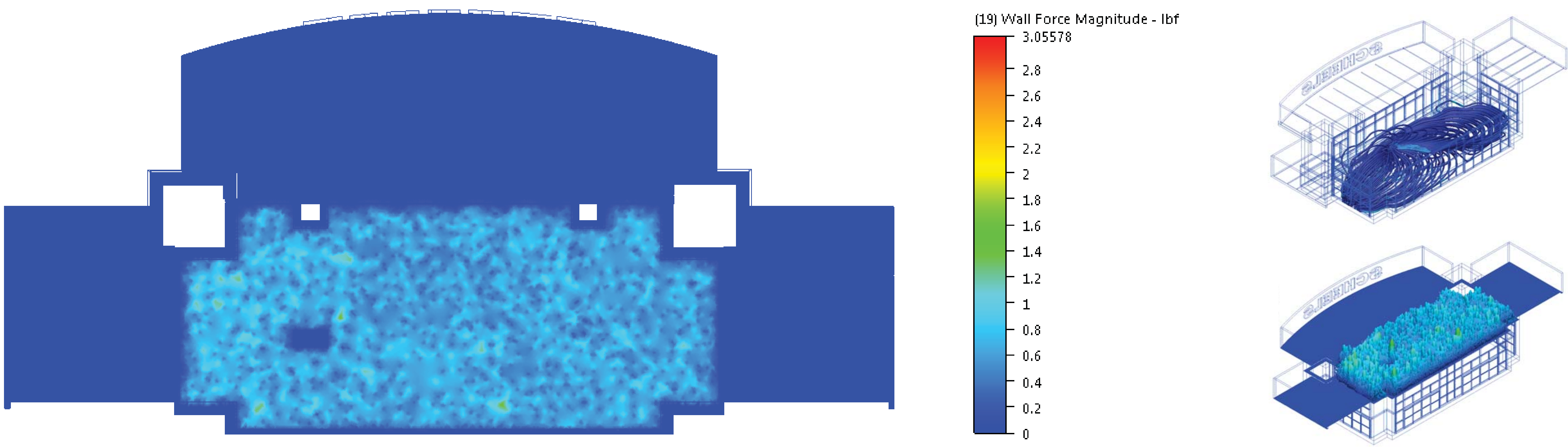


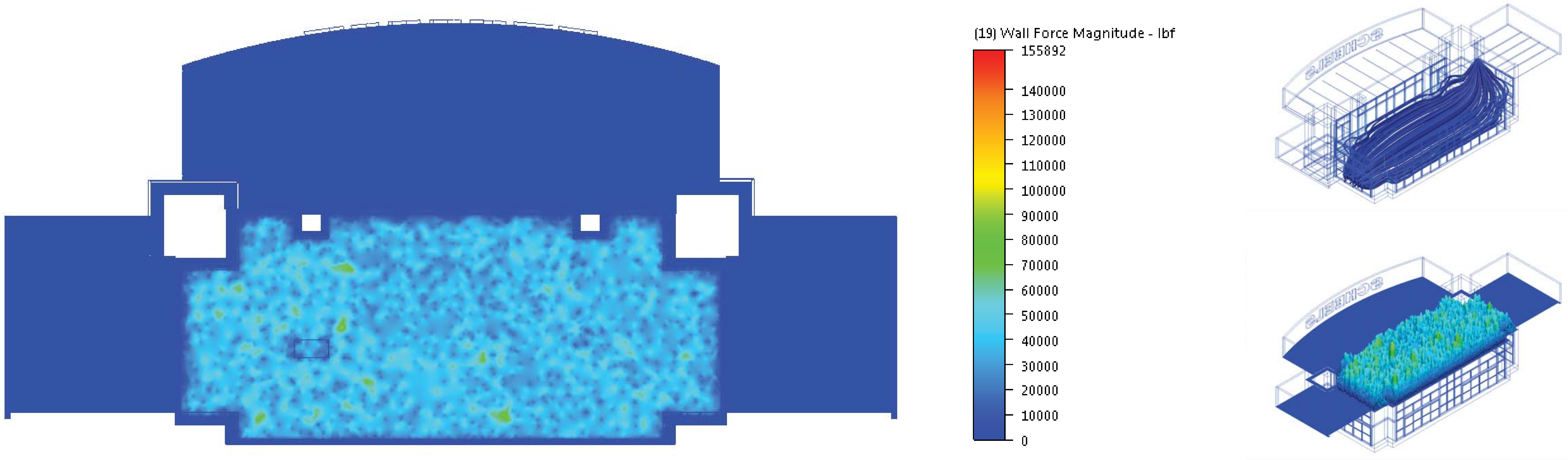
30.0 mph no outlet outlet incompressible air flow



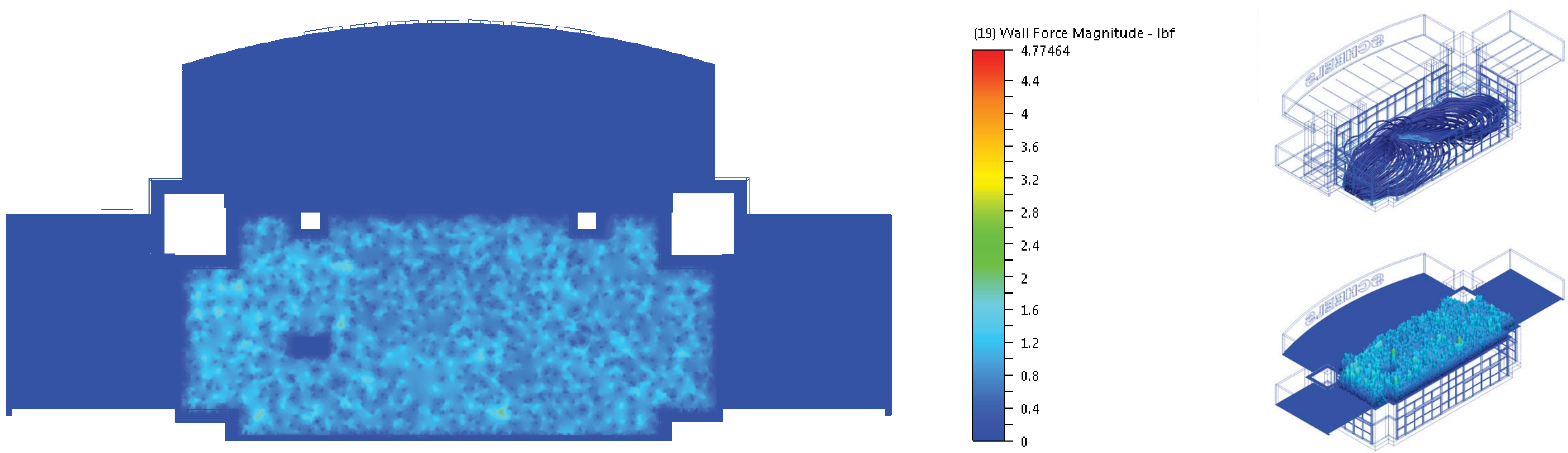


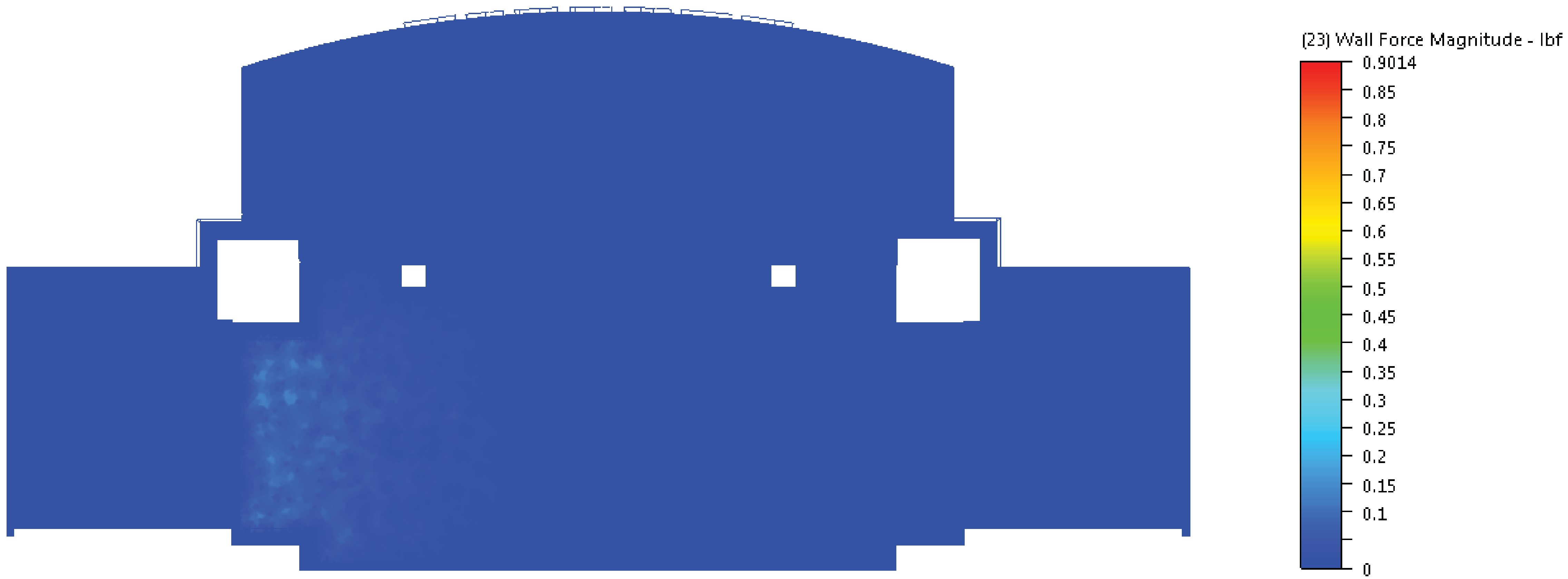
40.0 mph no outlet outlet incompressible air flow





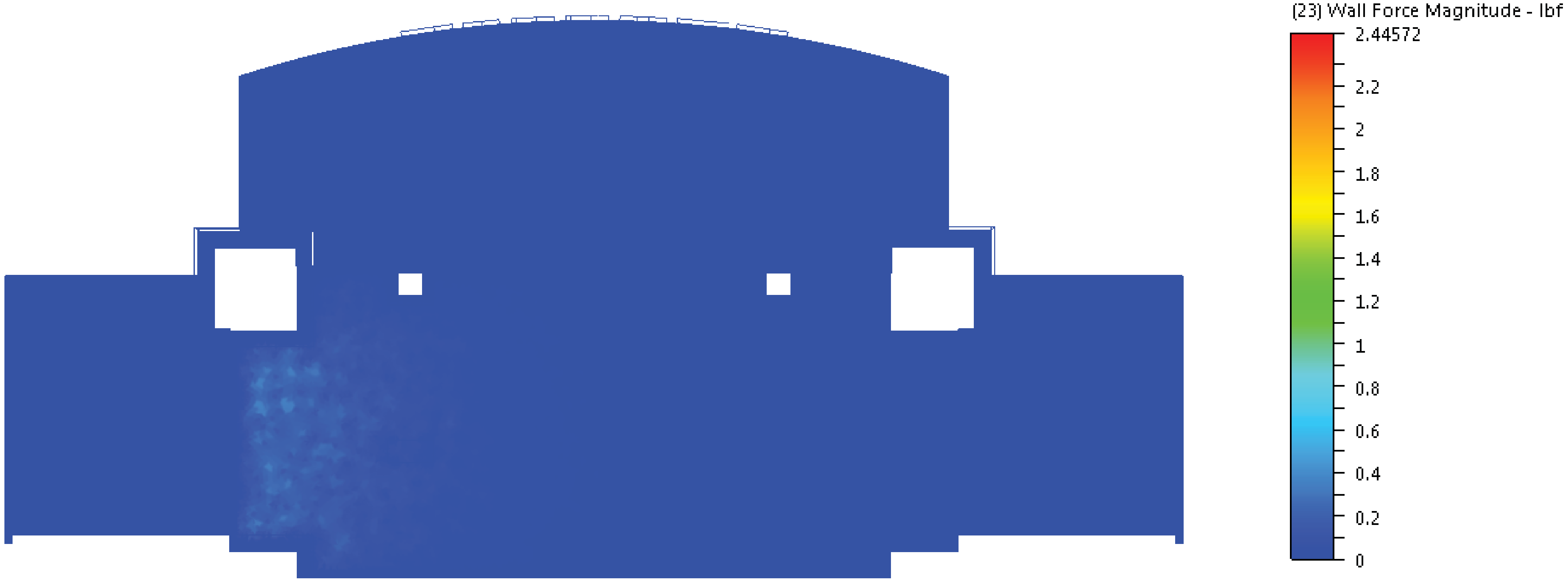
50.0 mph no outlet outlet incompressible air flow





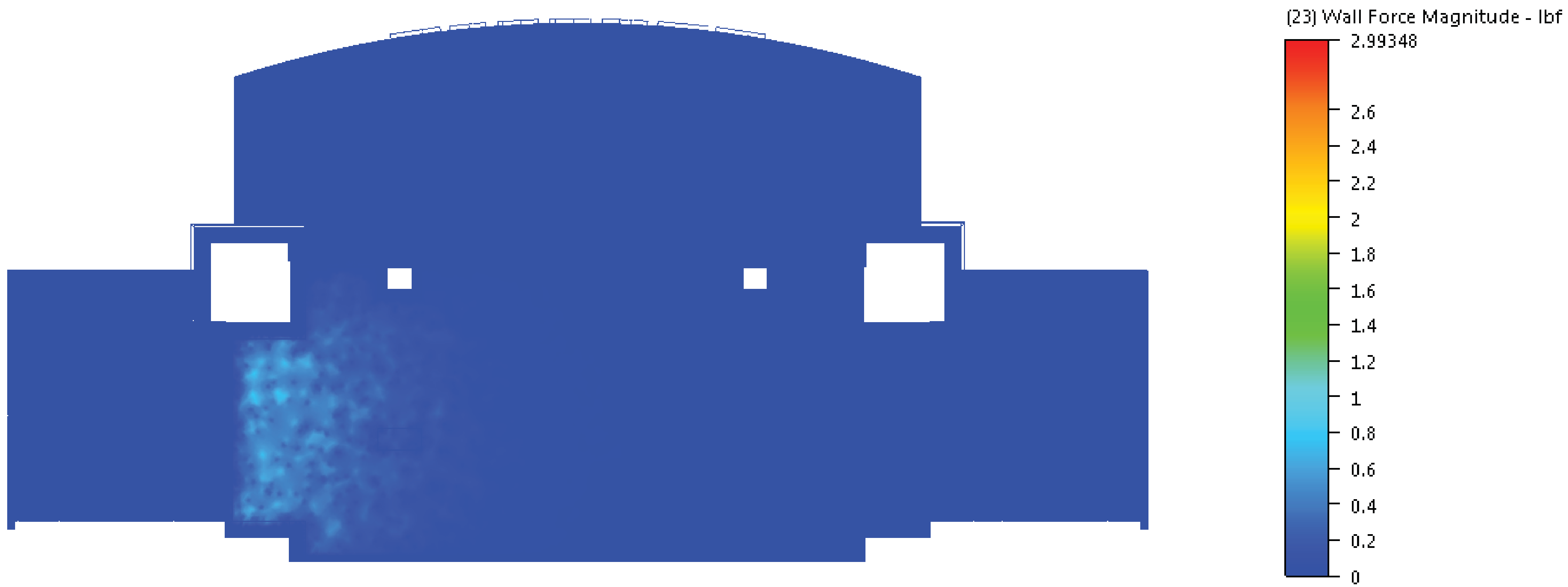
13.86 mph no outlet
30.00 mph no outlet

compressible air flow



40.00 mph no outlet
50.00 mph no outlet

compressible air flow



CONCLUSIONS

The completion of these analyses led to results which provided much of the information that was being sought. This will allow changes to be made to lessen the impact that wind has on the building and site as well as provide alternative solutions for future projects.

Using 3D computer models as a representational building model and then incorporating real, dynamic data from a specific situation for the determination of actual behavior is a real design strategy that can be used on both built and conceptual building models in order to improve the design.

IMPLICATIONS

The results of this research provide many possibilities in future design projects. For those in building design and construction, this research will provide information regarding how various pressures can affect the built environment, such as roof structure load amounts, snow accumulation, and wind paths and pressure in entry vestibules. By designing buildings for the existing weather conditions, many potential problems can be avoided. This allows for a more complete, workable building.

RESEARCH JOURNAL

WEEK 1

-introduction to the course and project proposal assignment

-research project proposal methods

WEEK 2

-install Robot Structural Analysis, Simulation CFD,Simulation Flex

-troubleshoot installation problems

-watch tutorials for new software programs

-meeting with R. L. Engebretson Co. to discuss project parameters

-develop expected schedule

-contact Judy at R. L. Engebretson Co. for Revit model

-begin literature review

-create sample Revit models for use in other programs

WEEK 3

-complete creation of trial models in Revit

-perform simulations using Simulation CFD 360

-testing of various programs

WEEK 4

-continue literature review

-read Research Methods

-begin problem statement

WEEK 5

-complete research problem statement

-review literature

WEEK 6

-download wind rose for Billings, Montana.

-calculate psi for inches of water

-complete Maya tutorials for animation

-import 3D model into Vasari

WEEK 7

-prepare simulation results according to the guidelines provided

-read Research Methods

-expansion of problem statement

-develop midterm report

-test maya roof structure

WEEK 8

-complete simulations and format results in InDesign

WEEK 9

-preparing sketchup model for Vasari

-determining wind conditions

-Flow Design simulations, spreadsheet and indesign

-Vasari, massing and report

-meeting with R.L. Engebretson Co

WEEK 10

-isolate the 3D model of the entry vestibule in Revit for import into Simulation CFD

-turning model windows solid

-complete Flow Design max frequency and velocity

WEEK 11

-complete the isolation of the entry vestibule to create air volume for the CFD simulation.

WEEK 12

-isolate entry vestibule

WEEK 13

-use Simulation CFD

-troubleshoot the simulation with entry vestibule, testing refinement options for the meshing.

-complete draft journal article

-run simulations of wind pressure in vestibule and test openings in ceiling to reduce pressure on the ceiling tiles.

WEEK 14

-rerun analysis in Flow Design

WEEK 15

-run analysis in Simulation CFD

WEEK 16

-meeting with RLE group

-work on journal article

WEEK 17

-develop final products for presentation

bibliography

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