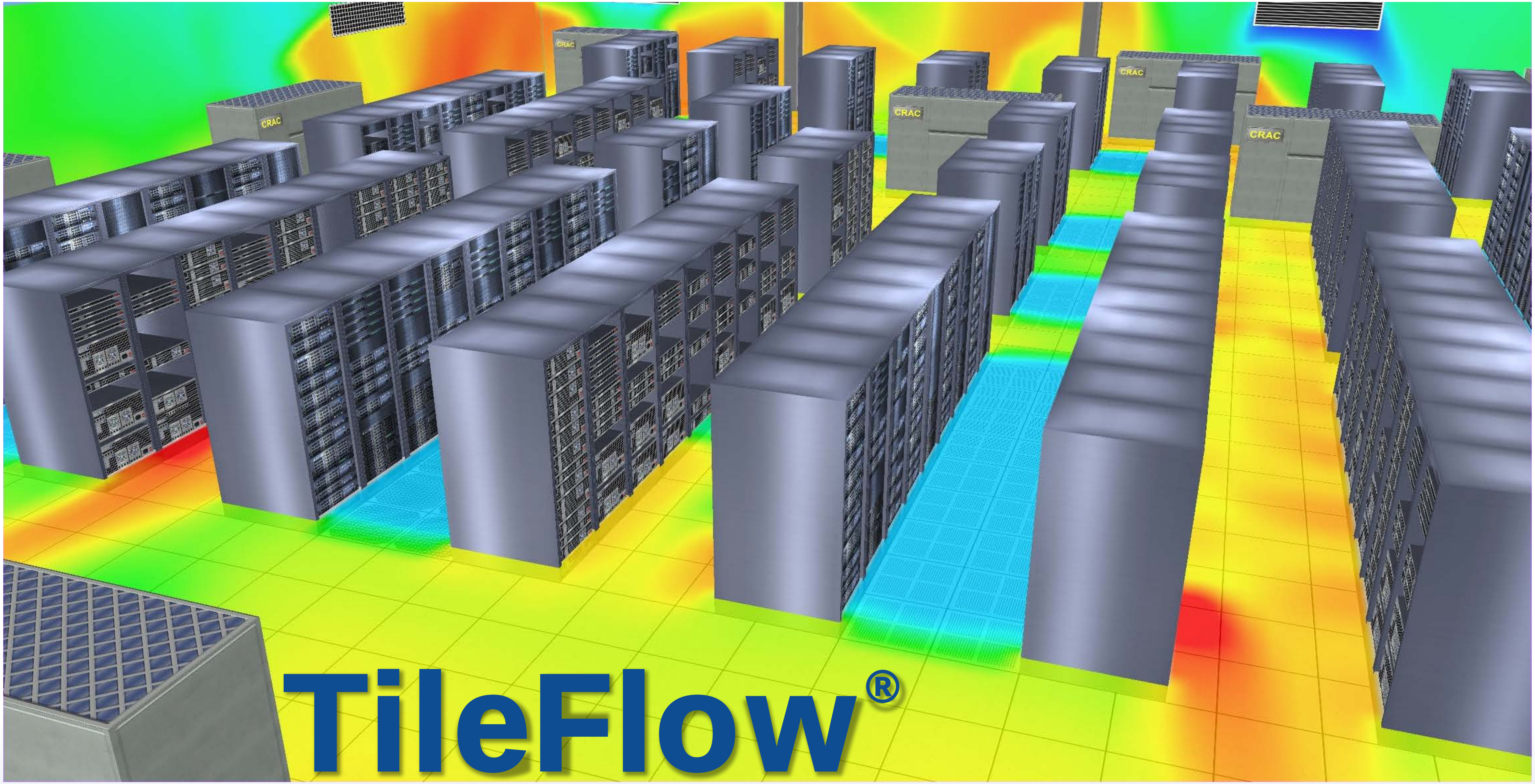


TileFlow®

Innovative Research, Inc.
A Computational Fluid Dynamics Company

About TileFlow

- Simulation tool based on computational fluid dynamics (CFD)
- Allows you to construct a computer model of your data center
- Gives complete information about the airflow pattern, pressures, and temperatures throughout the data center
- Has **predictive** capabilities
  - Shows the implications of proposed/future changes in the layout on the airflow and temperatures
  - Ideal for "what if" scenarios
- Is routinely used to:
  - Assess the current state of cooling
  - Plan modifications of current layout
  - Consider failure scenarios
  - Compare different cooling scenarios
  - Design cooling for new data centers
  - Identify energy wastage and save energy

TileFlow

Background

- Introduced in 2001
- First CFD product dedicated to data centers
- Extensively validated
- Backed by a team of CFD experts
- Used by major corporations worldwide

Distinguishing Features

- Customized for data centers
- Comprehensive, flexible, robust
- Unparalleled ease of use
- Unmatched solution speed
- Unrivaled (unlimited) technical support
- Modest computing resources

Comprehensive Software Tool

- Realistic display of objects
- Raised-floor or non-raised-floor configurations
- Choice of tile size
- Irregular shapes
- Downflow and upflow CRAC units
- Downflow CRAC units with front/rear discharge
- VFDs on CRAC units
- Pressure sensors below the raised floor
- Coolers, overhead units, rear-door heat exchangers
- Drop ceiling, ducted CRAC units, chimney racks
- Aisle containment
- Aisles tool
- Inlet/outlet vents
- Obstructions/partitions
- Variety of rack flow configurations
- Choices for specifying rack heat load/airflow demand
- Rack Builder to configure racks
- Import facility for rack/server data (DCIM/Excel)
- Extensive (editable) databases

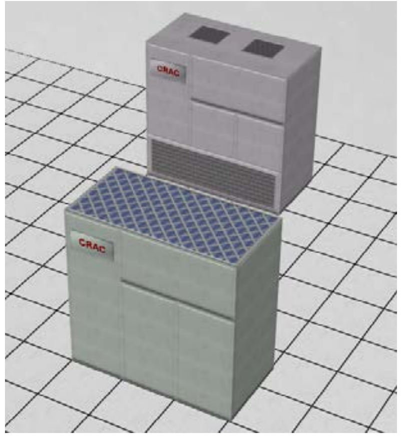
Comprehensive Software Tool

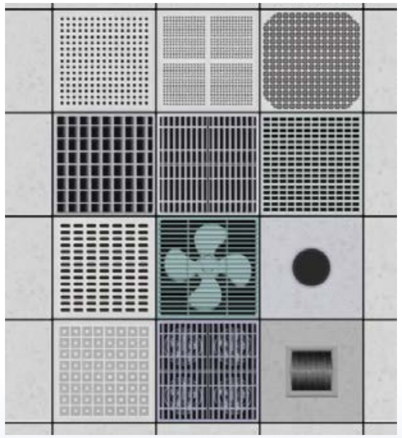
- Layout drawing import
- Choice of units (English/Metric)
- Customizable PDF and HTML reports
- Markup mode to annotate pictures
- Intuitive graphical displays/animation/movies
- Perspective and orthographic view
- Text/heat load on rack tops
- High-resolution screen capture
- Scheduler (batch processing)

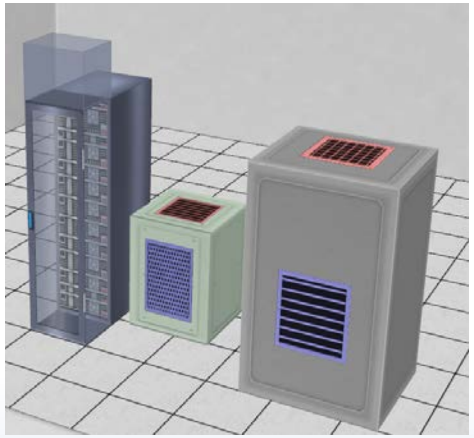
- Comprehensive results/reports
  - Airflow rates through perforated tiles/cutouts
  - Airflow pattern, pressures, temperatures
  - Rack inlet temperatures
  - Overheated racks
  - Performance of cooling devices
  - Movies, reports, Excel and text files
- Import facility for measured/sensor temperatures
- Temperature Distribution Based on Sensor Temperatures (for sample results, see slides 16-19).
- Provision for real-time temperature monitoring

The sensor module is available as an add-on, for an extra fee.

Realistic Display of Objects







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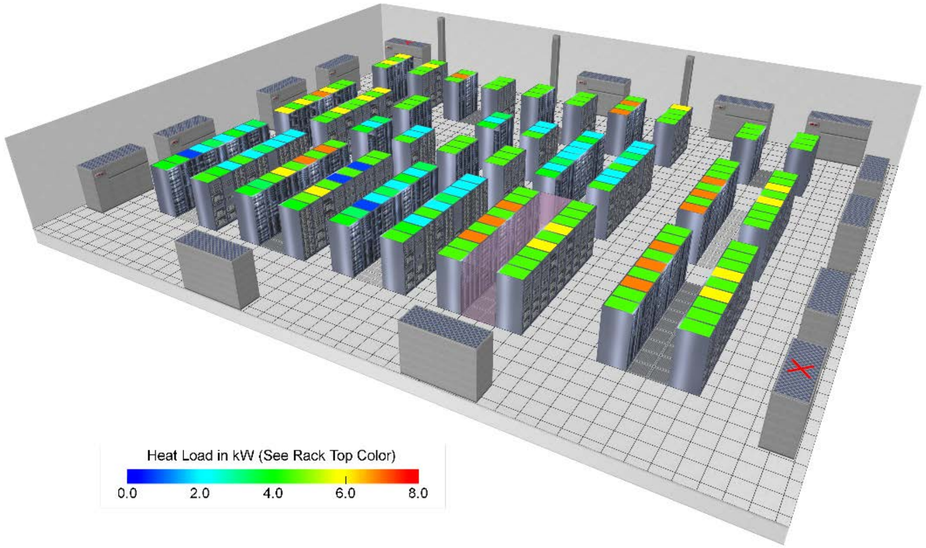
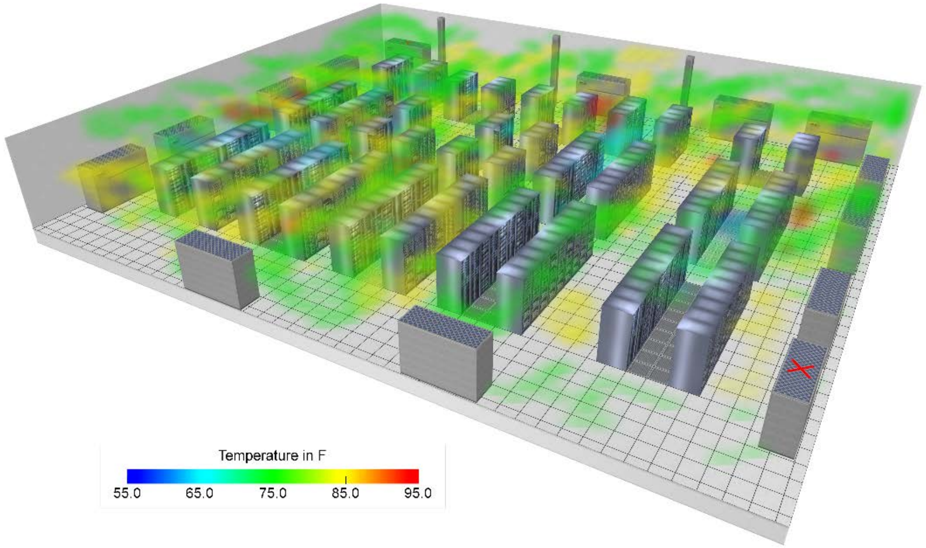
Sample Results



Data Center Layout and Distribution of Rack Heat Loads



Temperature Distribution in the Computer Room

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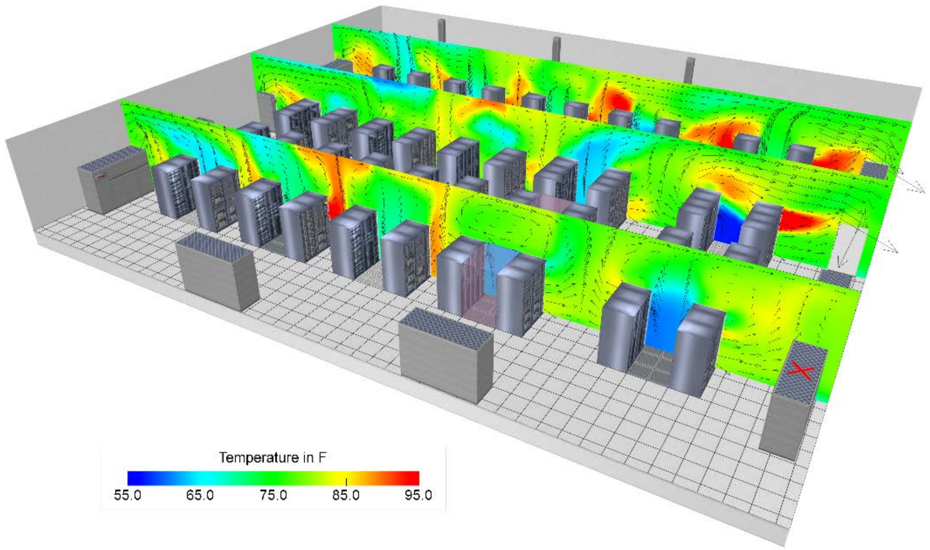
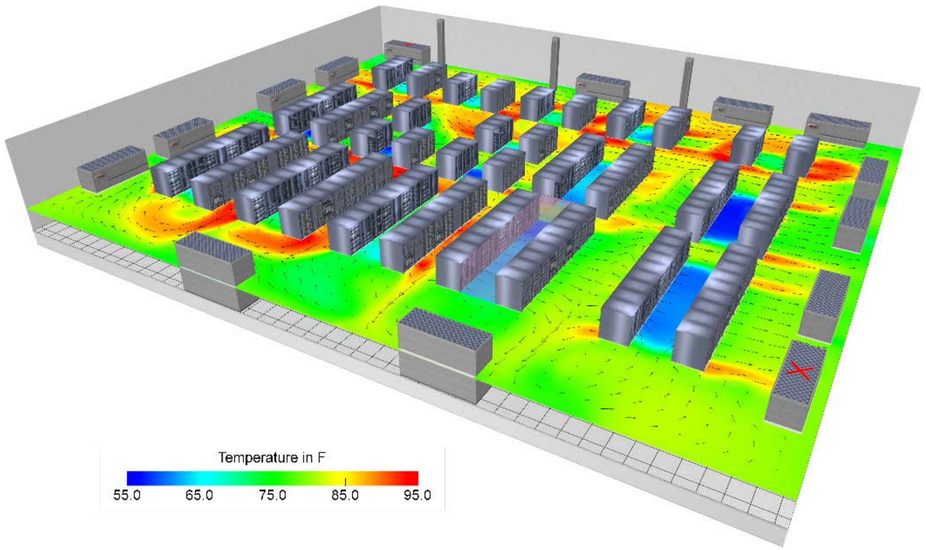
Sample Results



Temperature Distribution and Airflow Pattern on Vertical Planes



Temperature Distribution and Airflow Pattern on a Horizontal Plane

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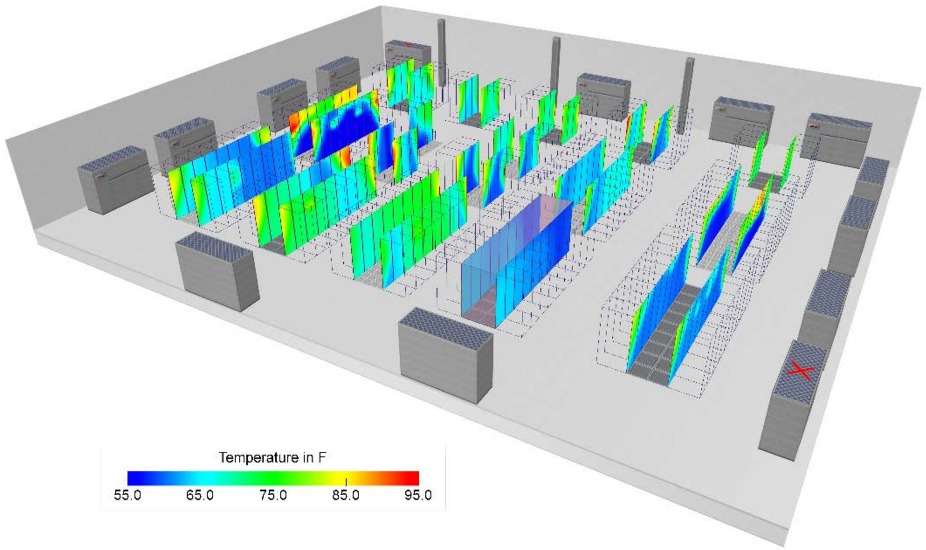
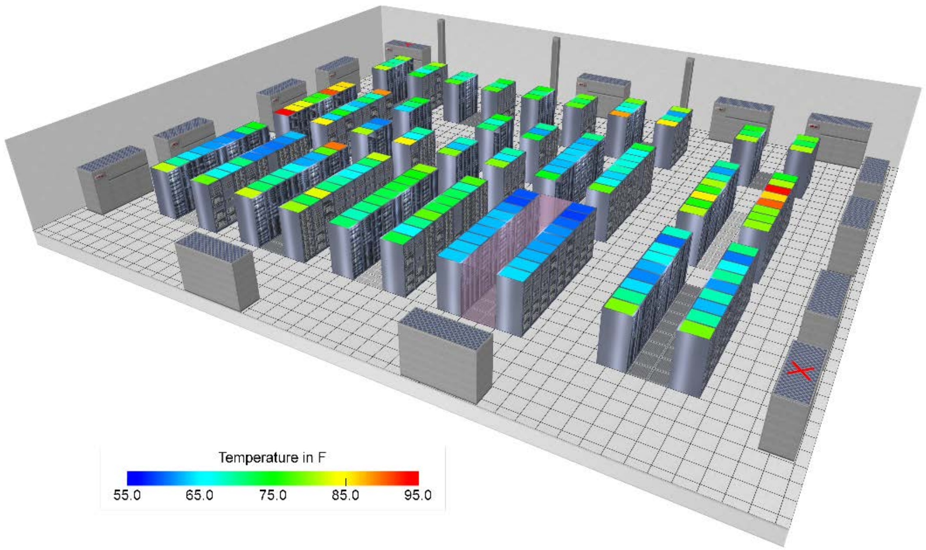
Sample Results



Rack Inlet Temperatures



Maximum Rack Inlet Temperatures

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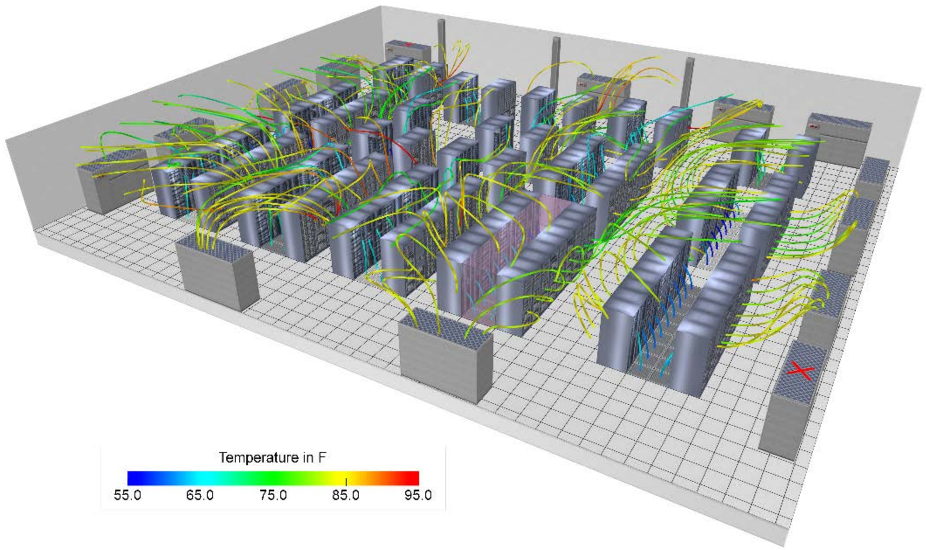
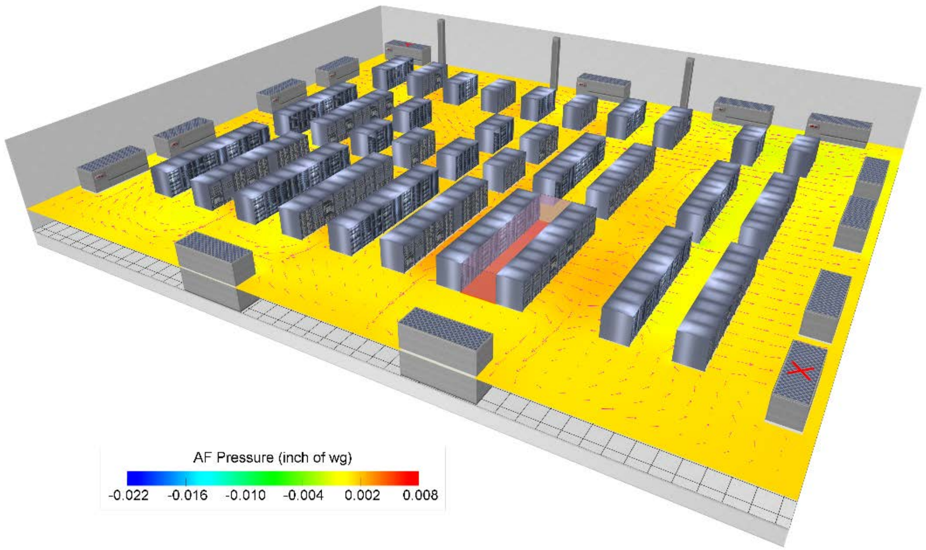
Sample Results



Airflow Pattern in the Computer Room



Pressure Distribution in the Computer Room

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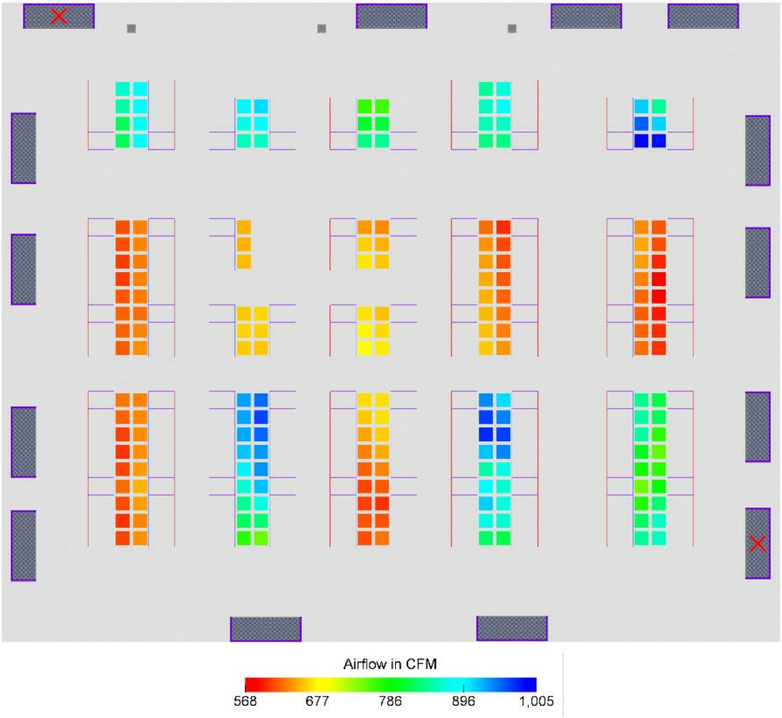
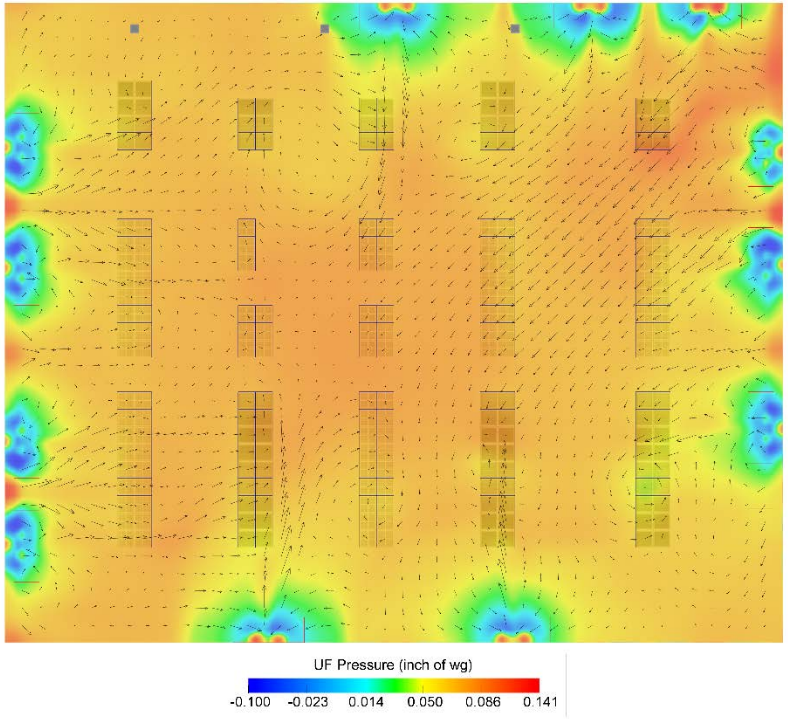
Sample Results

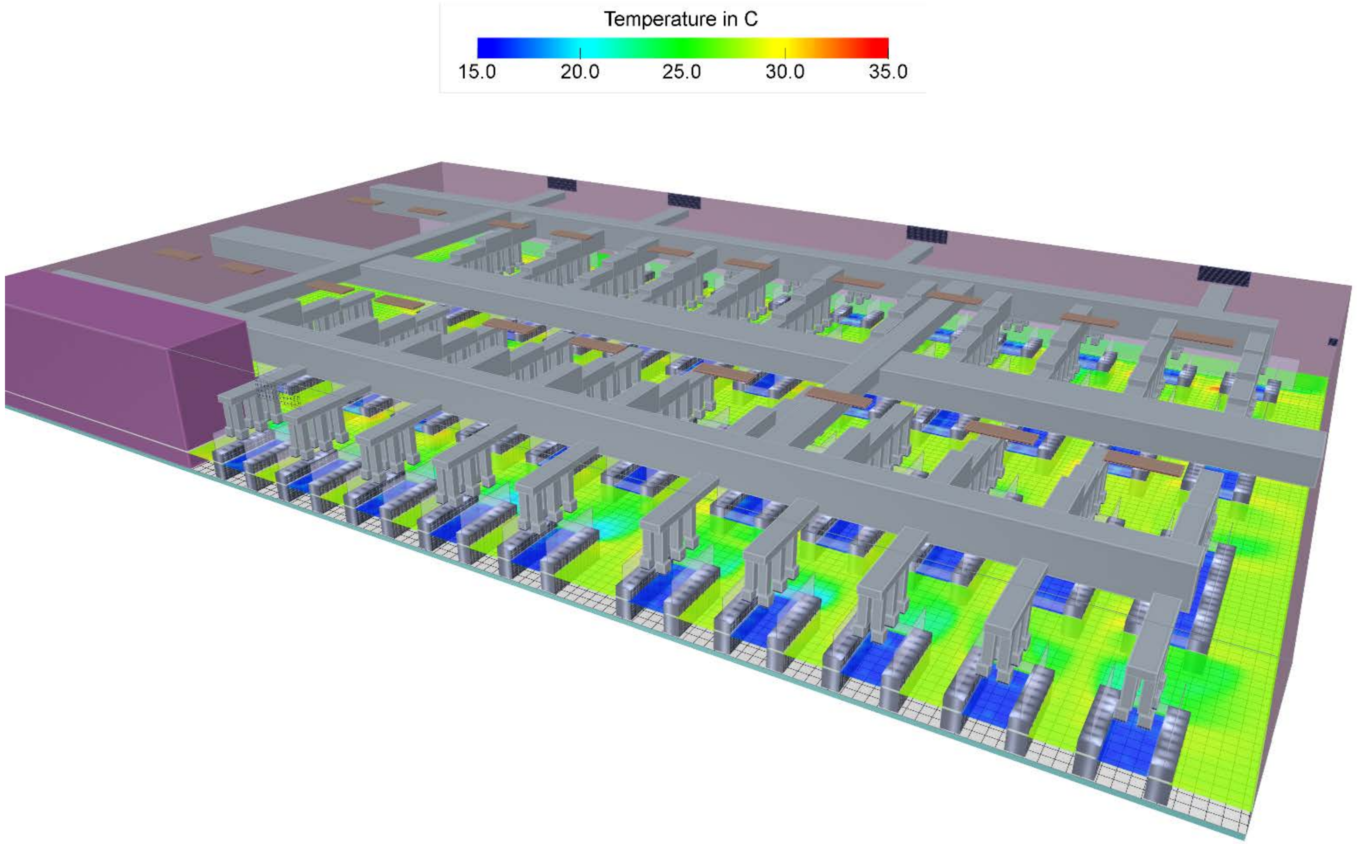


Distribution of Air Flow Rates Through Perforated Tiles



Pressure Distribution Below the Raised Floor

A Non-Raised-Floor Data Center



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Validation of TileFlow Results

TileFlow results have been extensively validated by us and by our customers, by comparing them with measurements of air flow rates, pressures, and temperatures in real-life data centers. Here we present selected results for one data center, at National Center for Environmental Protection (NCEP), Bethesda, Maryland, USA. The level of agreement between the predictions and measurements is typical of what we find in other data centers.

Validation of Results: NCEP Data Center

- Data center at National Center for Environmental Protection, Bethesda, MD
  - Floor size: 77 ft × 84 ft
  - Under-floor plenum height: 17 in.
  - Number of downflow CRAC units: 7
  - Total air flow rate from CRAC units: 74,100 cfm
  - Number of racks: 88
  - Total heat load: 488 kW
  - Rack heat load distribution
    - Approx. 7 kW for most racks; 25 kW for two racks
- Measurements by Dr. Roger Schmidt (IBM), presented at 2004 ASHRAE conference

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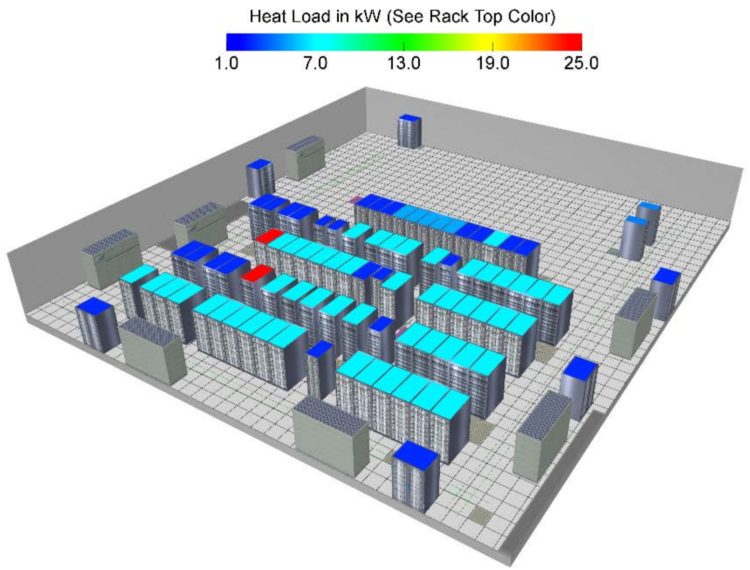
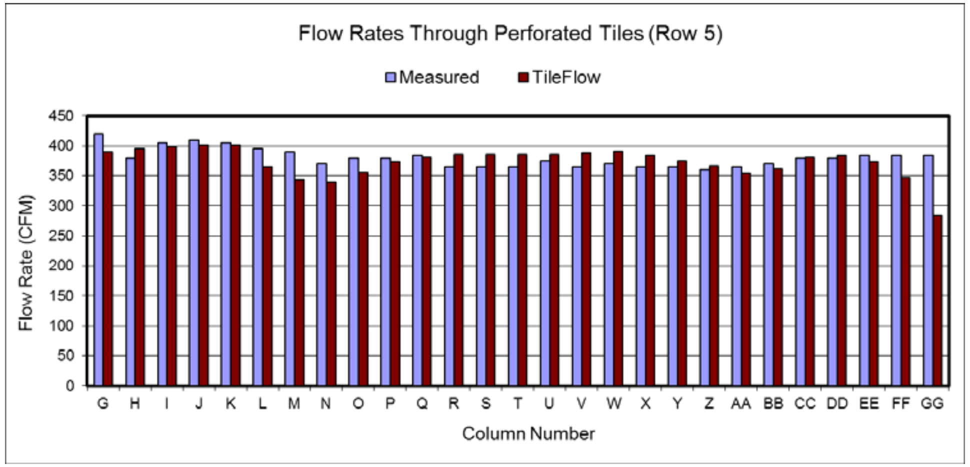
NCEP Data Center



Data Center Layout and Distribution of Rack Heat Loads



Air Flow Rates Through Perforated Tiles

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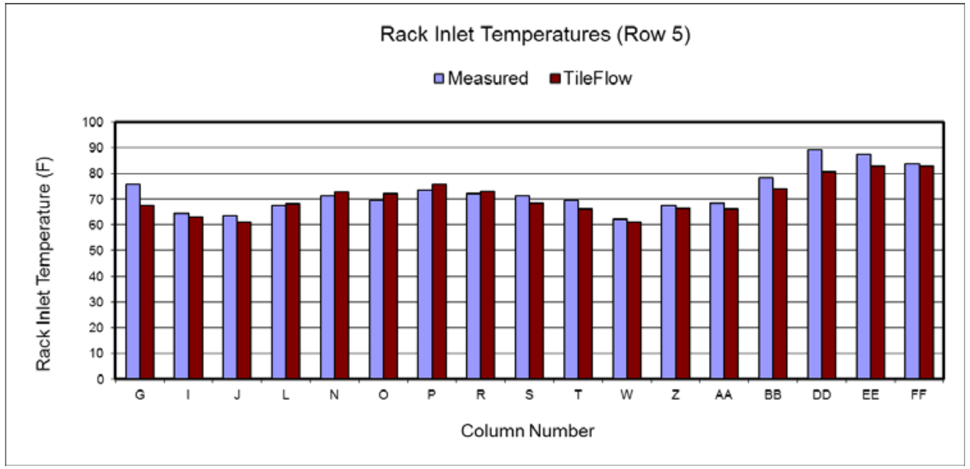
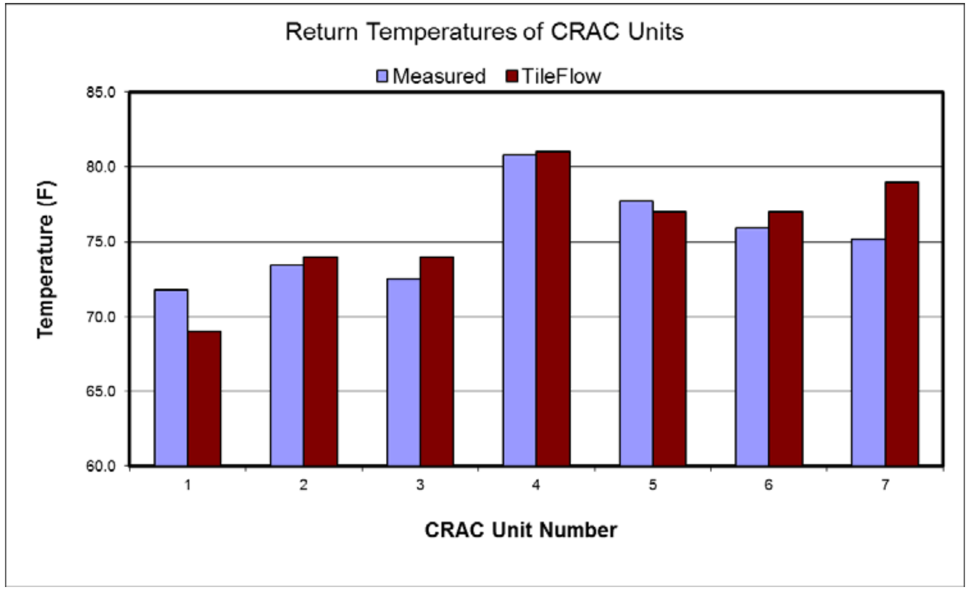
TileFlow®

NCEP Data Center



Rack Inlet Temperatures



Return Temperatures for CRAC Units

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Sensor-Based Temperature Distribution

So far we have described the CFD simulation capability of TileFlow. It can also calculate temperature distribution, which can be shown as temperature maps, based on temperatures provided by sensors or obtained from measurements.

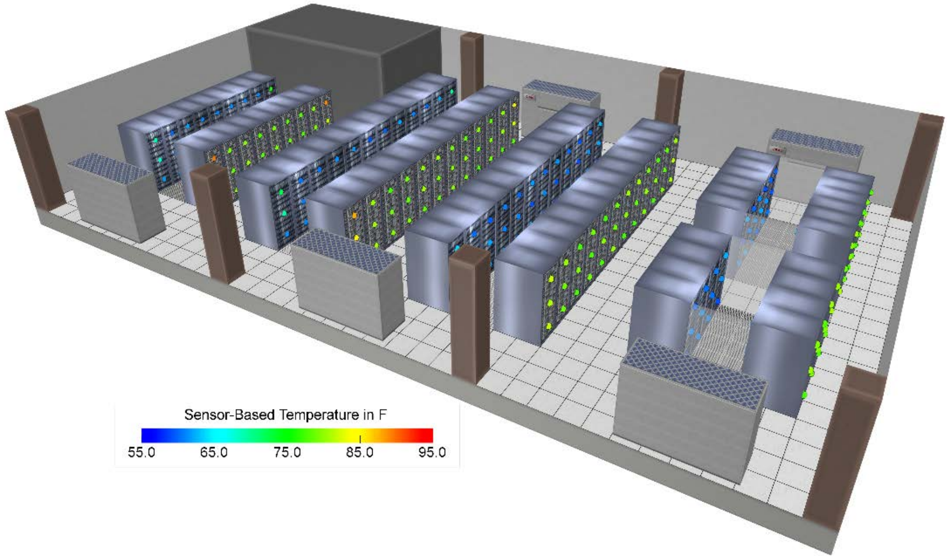
This additional capability is not part of the regular license; it is embodied in a sensor module, which is available as an add-on, for an extra fee.

In this section, this capability is described.

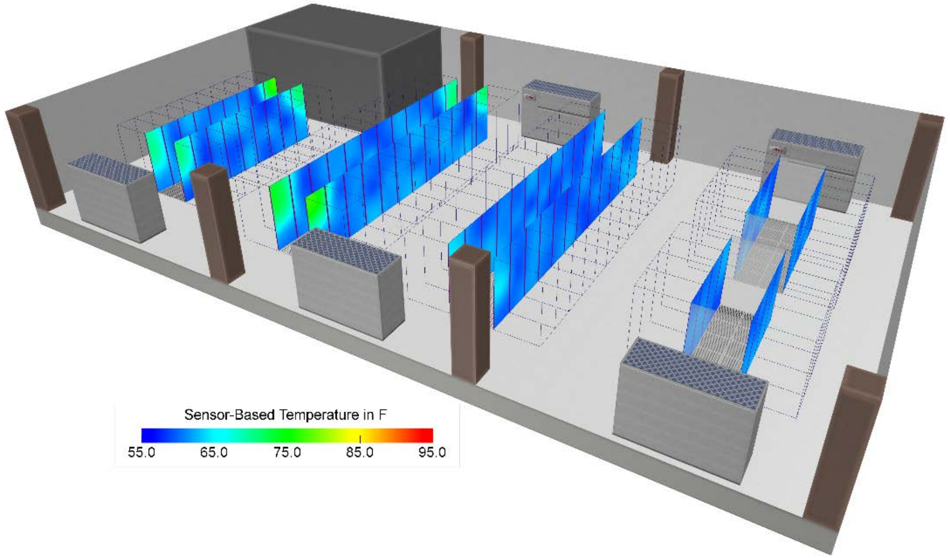
Sensor-Based Temperature Distribution

- Deployment of temperature sensors is gaining popularity.
- Sensor temperatures can potentially be used to describe the thermal conditions in the data center and make thermal-management decisions.
- For both these tasks, temperatures are needed at a large number of points.
- The number of sensors is usually limited.
- An interpolation scheme is needed to construct the temperature distribution from a limited number of sensor temperatures.
- TileFlow uses an advanced scheme that produces very accurate interpolated temperature fields.
- This scheme produces temperature distributions that agree well with those given by CFD simulations.

Sensor-Based Temperatures: Sample Results



Sensor Locations and Temperatures



Rack Inlet Temperatures

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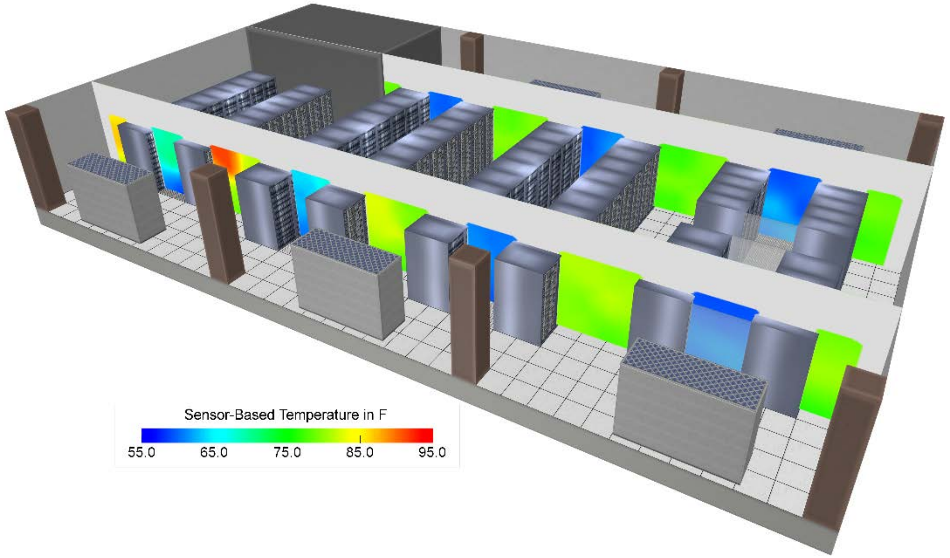
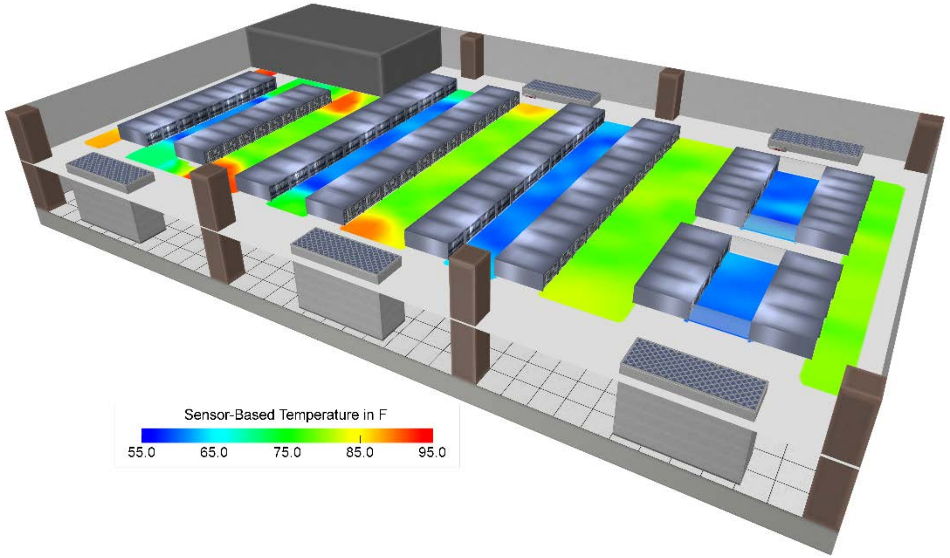
Sensor-Based Temperatures: Sample Results



Sensor-Based Temperatures on Vertical Planes



Sensor-Based Temperatures on a Horizontal Plane

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License Options

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License Options

- Single-computer license
  - Allows you to run TileFlow on one specific computer.
- Network (Site/Corporate/Global) license
  - Allows you to install TileFlow on any number of computers, but it can be run on only one computer at a given time (one concurrent user). The number of concurrent users can be increased by purchasing additional licenses. For example, for two concurrent users, you will need two licenses.
- License fee covers
  - Software updates/upgrades
  - Online training
  - **Unlimited** technical support
- License Period
  - Standard licenses are annual
  - Shorter-term and multiyear licenses are also available

About the TileFlow Team

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Our Contributions

- TileFlow team is a pioneer in airflow modeling in data centers:
  - **First** to build the under-floor computational model (2000)
  - **First** to explain the cause of nonuniform airflow distribution (2000)
  - **First** to introduce a CFD product specific to data centers (TileFlow, 2001)
  - **First** to quantify and measure the amount of air leakage through the raised floor
- We have published numerous articles in journals and conference proceedings. (For a partial list, see Slides 25–26.)
- We have written white papers/technical notes on topics related to airflow modeling and measurements in data centers. (For a partial list, see Slide 27.)
- We are often invited to give educational seminars at conferences and trade shows.
- We have developed measurement techniques, which have been widely adopted by our clients and other data center professional.
- Our president has written **The Book on CFD: S. V. Patankar, Numerical Heat Transfer and Fluid Flow,** Taylor and Francis.

Publications

- Optimizing Cooling Performance of a Data Center. ASHRAE Journal, Vol. 60, No. 7, pp. 22-29, July 2018.
- CFD Modeling of an Existing Raised-Floor Data Center. Semi-Therm 29. 2013.
- Cold-Aisle and Hot-Aisle Containment. 7×24 Magazine, Fall 2012.
- Use of Passive Rear-Door Heat Exchangers to Cool Low to Moderate Heat Loads. ASHRAE Paper No. ML-11-C004. 2011.
- Airflow and Cooling in a Data Center. ASME Journal of Heat Transfer, Vol. 132, pp. 073001–0703001-17, July 2010. (Max Jakob Award Paper)
- CFD Simulation of Airflow and Cooling in a Data Center. ICHMT International Symposium on Advances in Computational Heat Transfer, Marrakech, Morocco. 2008.
- Prediction of Distributed Air Leakage in Raised-Floor Data Centers. ASHRAE Trans., Vol. 113, Part 1, pp. 219-226, 2007.
- Analysis of Airflow Distribution Across a Front-to-Rear Server Rack. Paper No. IPack2007-33574, ASME InterPack '07.

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Publications (Contd.)

- Airflow Distribution Through Perforated Tiles in Raised-Floor Data Centers. Building and Environment, Vol. 41, pp. 734-744, 2006.
- Distributed Leakage Flow in Raised-Floor Data Centers. Ipack2005-73273. ASME InterPack'05. 2005.
- Distribution of Cooling Airflow in a Raised-Floor Data Center. ASHRAE Trans., Vol. 110, Part 2, pp. 629-635, 2004.
- Raised-Floor Data Center: Perforated Tile Flow Rates for Various Tile Layouts. ITherm 2004.
- Use of Computational Fluid Dynamics for Calculating Flow Rates Through Perforated Tiles in Raised-Floor Data Centers. HVAC&R Research, Vol. 9, pp. 153-166, 2003.
- Techniques for Controlling Airflow Distribution in Raised-Floor Data Centers. InterPack2003-35282. InterPack'03. 2003.
- Measurements and Predictions of Flow Distribution Through Perforated Tiles in Raised-Floor Data Centers. Ipack2001-15728.

White Papers

- Relationship Between Heat Load and Cooling Airflow Rate.
- A Comparison of Back-to-Back and Distributed Arrangements for Placing the CRAC Units.
- Distributed Leakage Airflow in Raised-Floor Data Centers.
- Airflow Modeling: An Effective Tool for Improving Cooling Performance of Data Centers.
- Application of TileFlow to Improve Cooling in a Data Center.

For More Information:

- Visit our website: TileFlow.com
- Email: info@TileFlow.com
- Call: +1 (763) 231-1200

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