HVAC & Air Distribution Basics: Considerations for Mitigating Viral Spread

Taylor Suess, P.E., Research Associate

Scott Deprez, Undergraduate Research Assistant

Stephen Gent, Ph.D., Professor

Mechanical Engineering

South Dakota State University, Brookings, SD

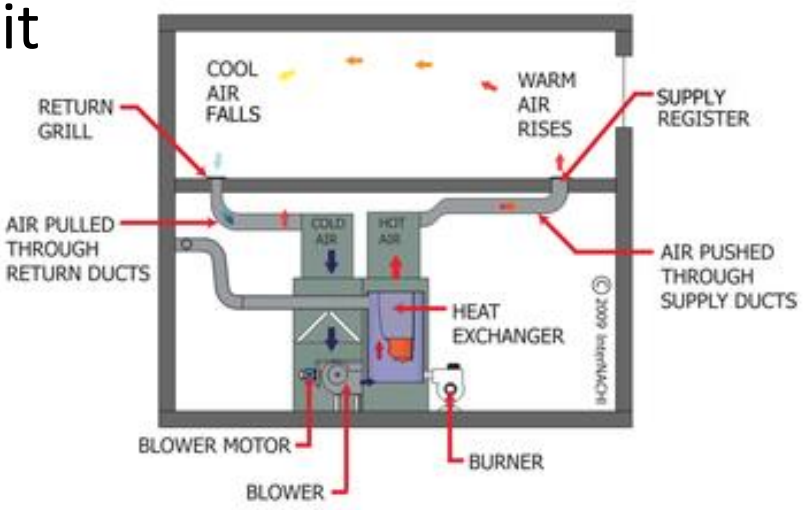
SOUTH DAKOTA STATE UNIVERSITY

Outline

- HVAC & Air Distribution Introduction
- Distinguishing between supply diffusers and return grilles
- How supply diffuser and return grille location affects room airflow
- Positives and negatives of fans, including considerations for strategic placement
- Case studies

HVAC Introduction

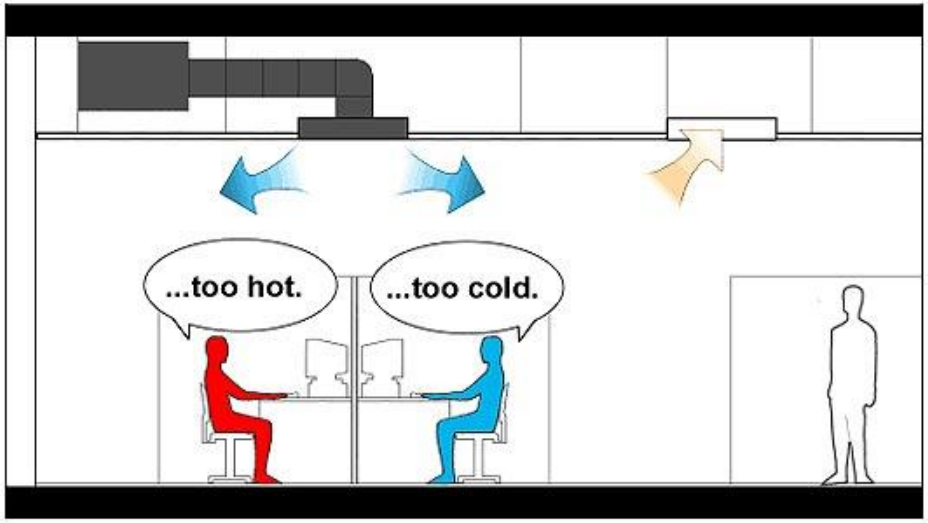
- Combination of return air from rooms and outside air ventilation is mixed at a central air handling unit
- Air is conditioned (heated or cooled) at the unit
- Conditioned air is blown through ductwork to a discharge location into a room (supply diffuser)
- Air flows through the room
- Eventually, air recirculates back to a return grille
  - Either travels back to the air handling unit or is exhausted outside



https://www.insideoutinspectionsplus.net/

HVAC Introduction

- Amount of airflow required in a room is calculated based on a variety of factors, including:
  - Square footage
  - Typical number of occupants
  - Exterior walls and windows
  - Heat from equipment
- HVAC systems are typically designed primarily around thermal comfort, NOT internal airflow paths



https://cbe.berkeley.edu/underfloorair/thermalcomfort.htm

Supply vs. Return

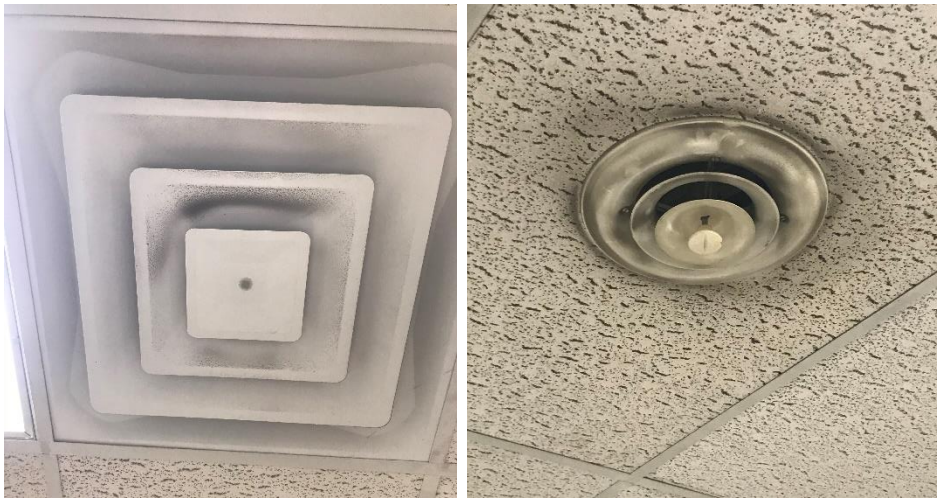
- First step to think about airflow patterns in a room is to locate and distinguish between the supply diffusers and return grilles

Typical supply:

- Louvered/baffled face
- Residue tends toward outside of diffuser face
- Typically more of these in a room

Typical return:

- Simple, grated face
- Residue tends to cake onto grate itself
- Typically only 1-2 in a room

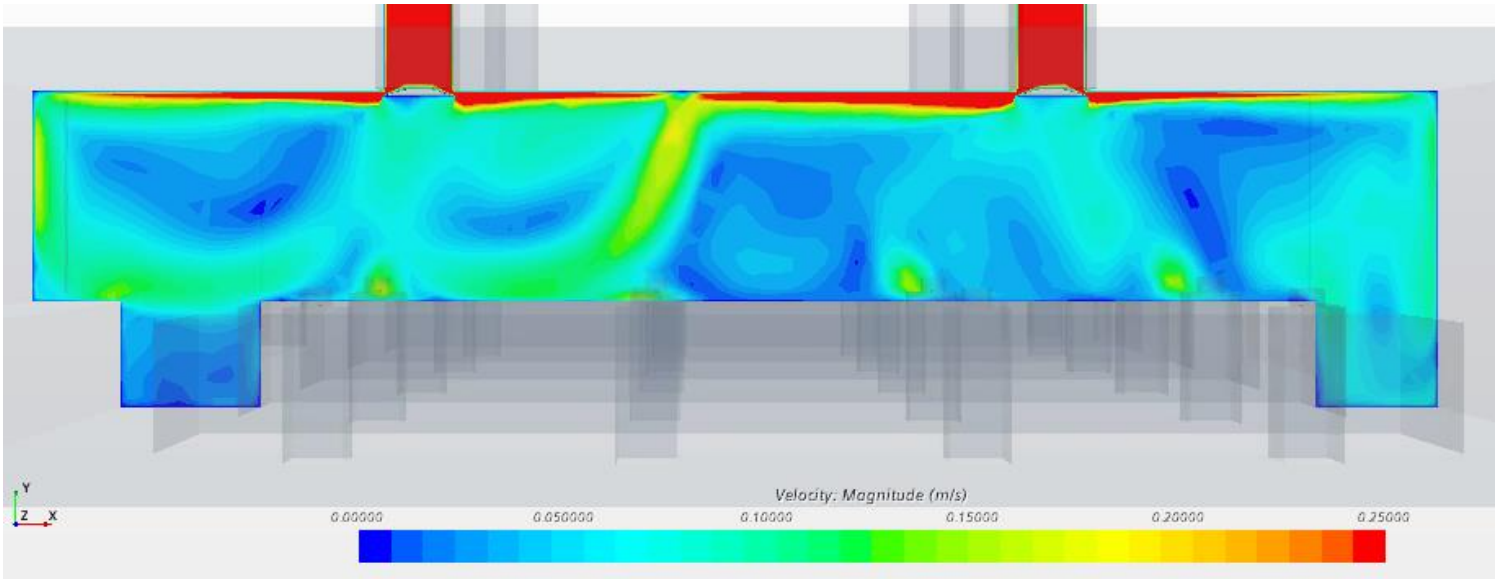


Several types of typical supply diffusers

Typical return grille

Supply Air Patterns

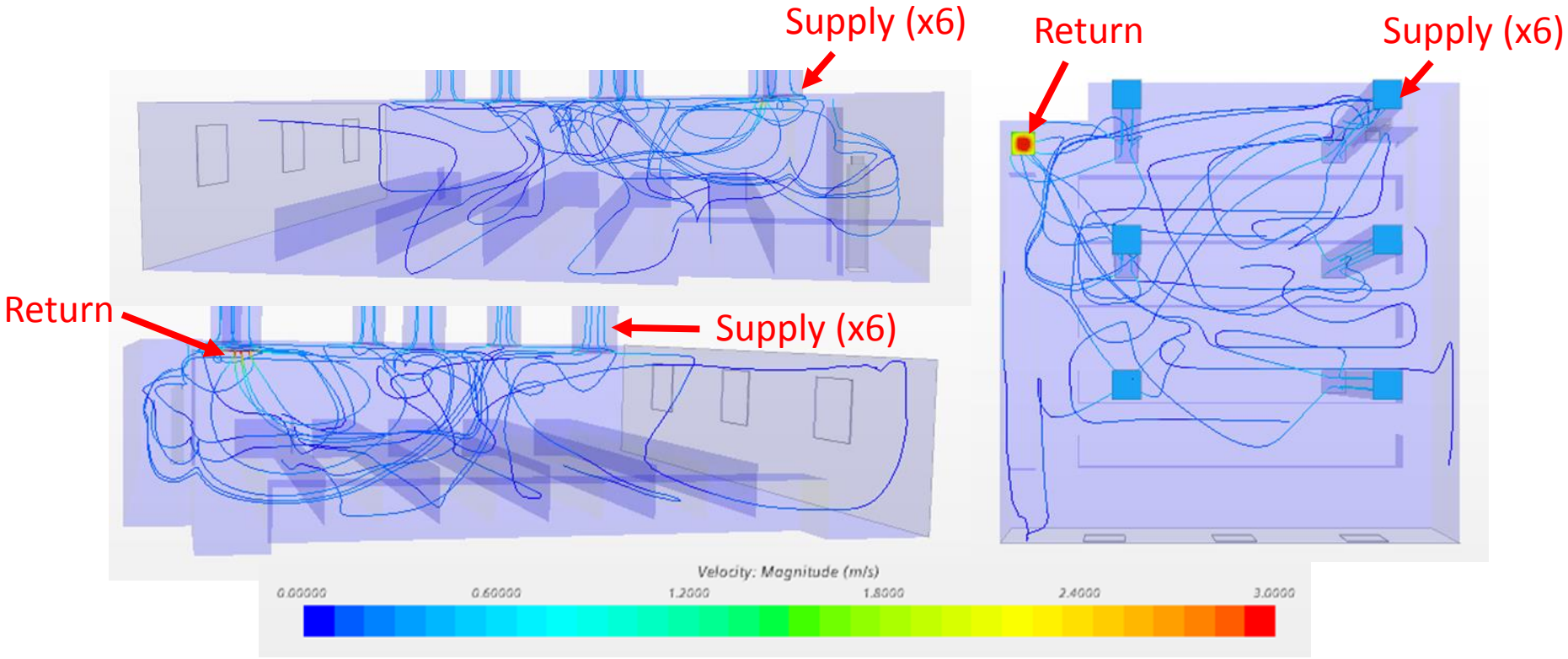
- Why does the residue tend to form around the outside of a supply air diffuser?
  - "Coanda effect"
    - Air comes into the room at high velocity (low pressure)
    - Room air (low velocity, high pressure) pushes air stream upward based on pressure difference (high pressure flows toward low pressure)
    - Airflow "clings" to the ceiling until it slows and expands, falling toward the floor



Typical airflow pattern in a classroom setting

Supply Air Patterns

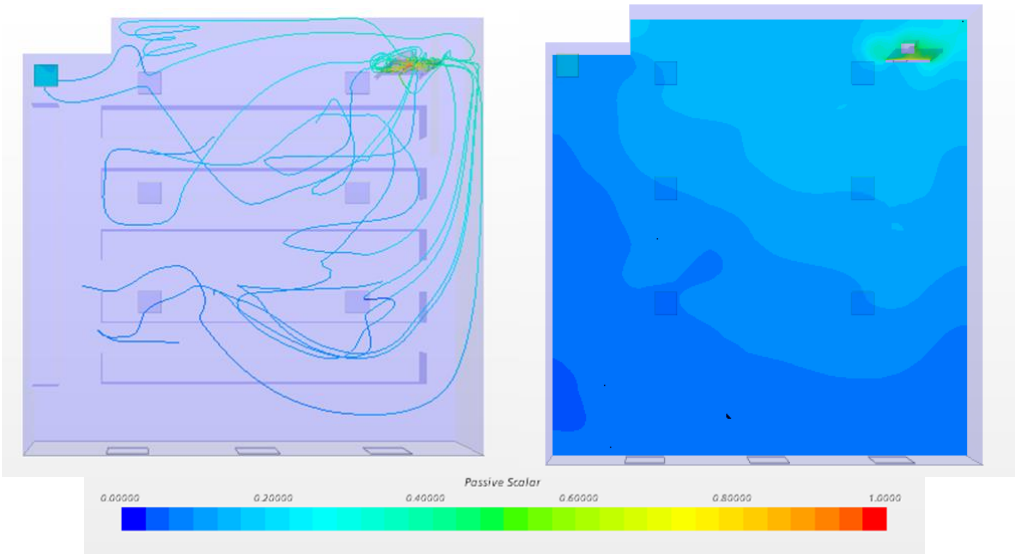
- Once the air falls, it mixes within the room and migrates back toward the return grille
  - With ceiling supply and ceiling return, most air will have a minimum 2 passes through the occupancy “breathing zone”
  - Warm air rises, cool air falls, which will also affect how the airflow mixes



Typical airflow pattern in a classroom setting

Supply Air Patterns

- Some primary objectives with regards for airflow for limiting potential for viral spread in a space:
  - Limit the number of air passes through the “breathing zone”
    - Ex., air supplied low (in-floor) and returned high (ceiling) promotes a single pass of air through the “breathing zone”
    - Ex., box and ceiling fans, when not placed strategically, create more mixing of the room air, increasing the number of passes through the “breathing zone”
  - Allow a free path for aerosols emitted by an occupant (breathing, coughing, talking, etc.) back to the return (filtered out by unit)



Aerosol dispersion (left) and aerosol concentration (right) from a teacher in a classroom setting, with a teacher behind a barrier

Box & Ceiling Fans

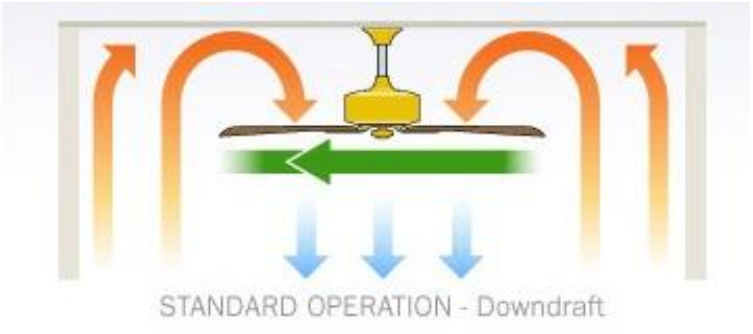
- Fans do not actually cool a space, but provide sensible “cooling” to the individuals
  - Air blows over skin, which increases heat transfer and evaporation of sweat
  - “Wind chill effect”
- Considerations for strategic placement of fans may show that they are beneficial in some spaces

https://www.imgh.org/

https://www.nytimes.com/wirecutter/

Box & Ceiling Fans

- Some potential examples:
  - Box fan blowing across occupants toward return
    - Promote faster return of supply air to the return ductwork
  - Ceiling fan run in reverse during cooling mode
    - Contrary to typical convention (forward in summer, reverse in winter)
    - Cool air falls
    - Fan would pull cool air upward past occupants and try to keep air high to push toward return



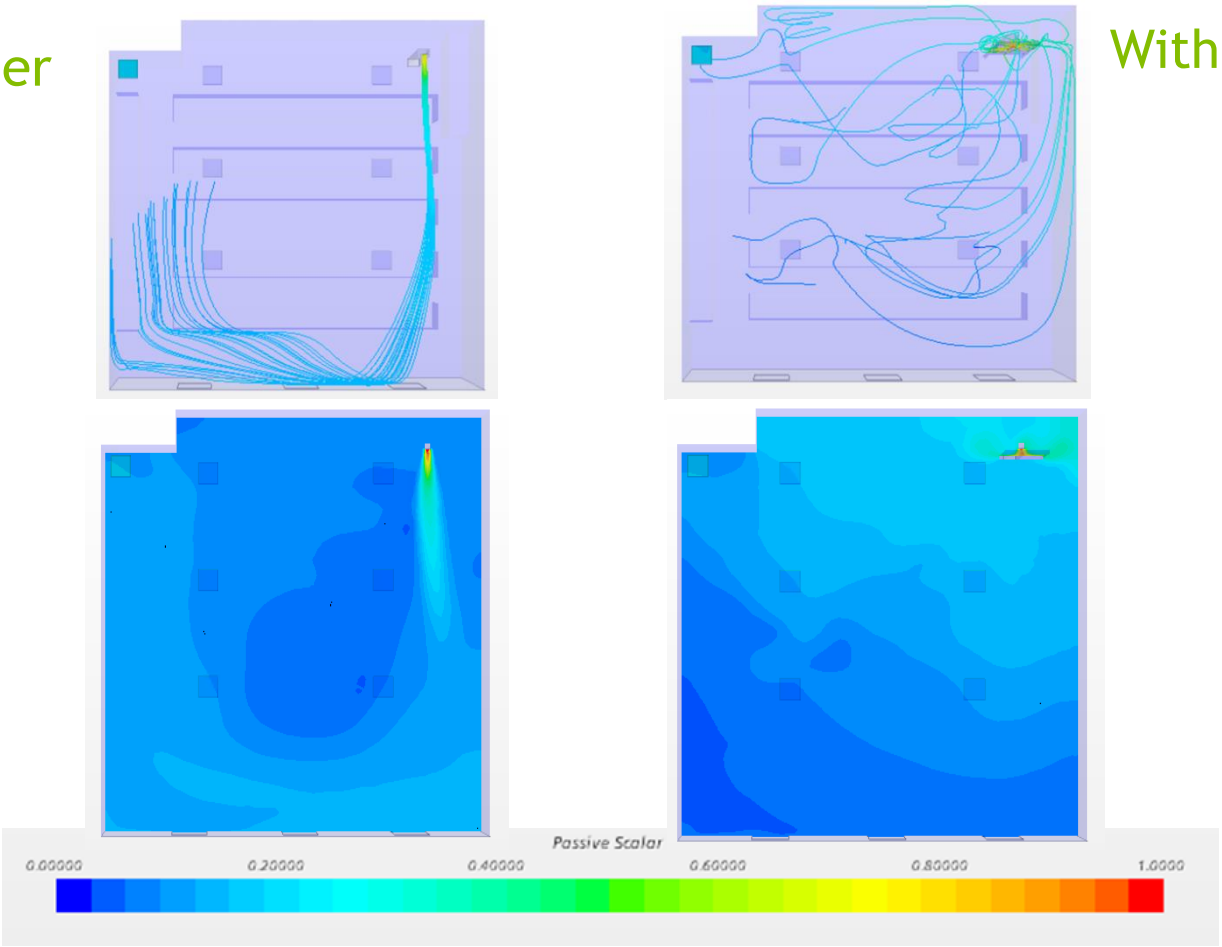
https://home.howstuffworks.com/ceiling-fan.htm

Case Study 1: SDSU Classroom

- CFD simulations compared existing room layout with addition of a barrier in front of the teacher
  - Dispersion of teacher aerosols in room

Without barrier

With barrier

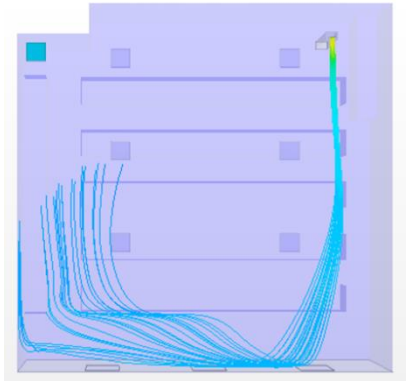


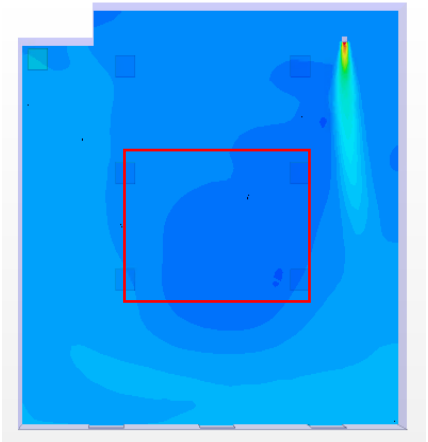
Case Study 1: SDSU Classroom

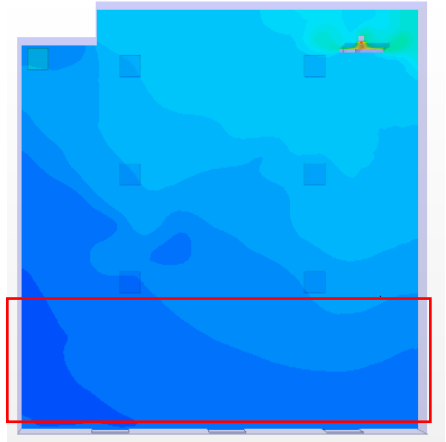
Potential recommendations

- Provide teacher barrier and encourage student seating in back of room, behind the furthest supply air diffusers
- Without barrier, encourage student seating toward middle of room, between supply air diffusers

Without barrier







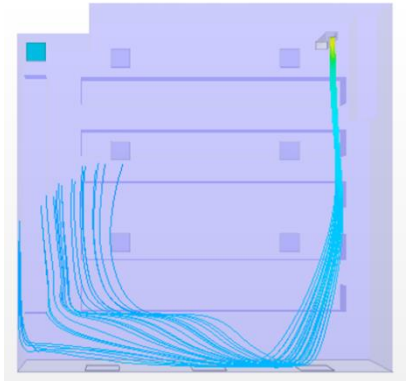
With barrier

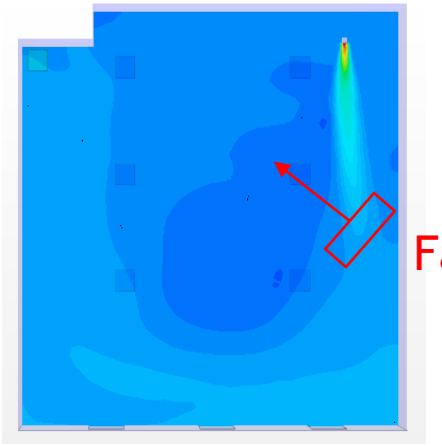
Case Study 1: SDSU Classroom

Potential recommendations

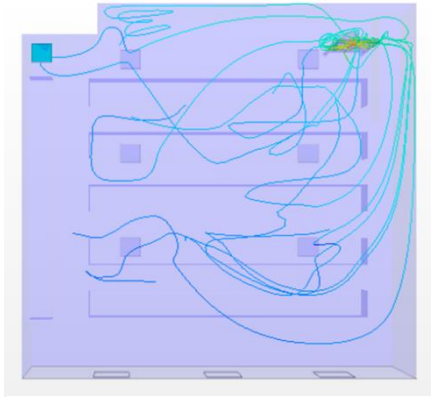
- Strategic location of box fan to push aerosols from teacher toward return grille
  - Students in back of classroom, both with and without barrier
  - Provide open path between box fan and return grille

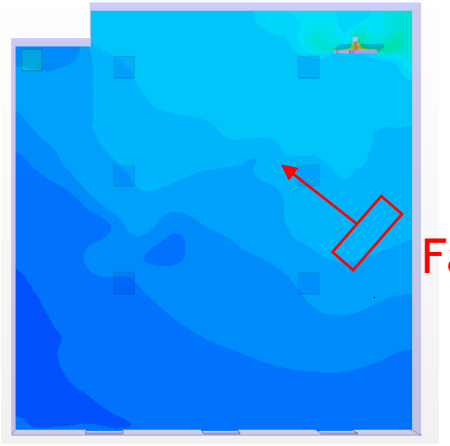
Without barrier





With barrier





Case Study 1: SDSU Classroom

Potential recommendations

- Re-orient the room:
  - Rotate typical room function 90-degrees clockwise:
    - Teacher speaks toward return grille (right-to-left)
    - Students face teacher (facing right), offset from teacher (toward bottom of images below) to provide clear path to return grille
    - Relocate chalk boards, projector equipment, etc.
    - Avoid barriers in this scenario
      - Limit mixing of aerosols in different air streams