Simulating the Effect of Local Environmental Conditions on Human Thermal Comfort

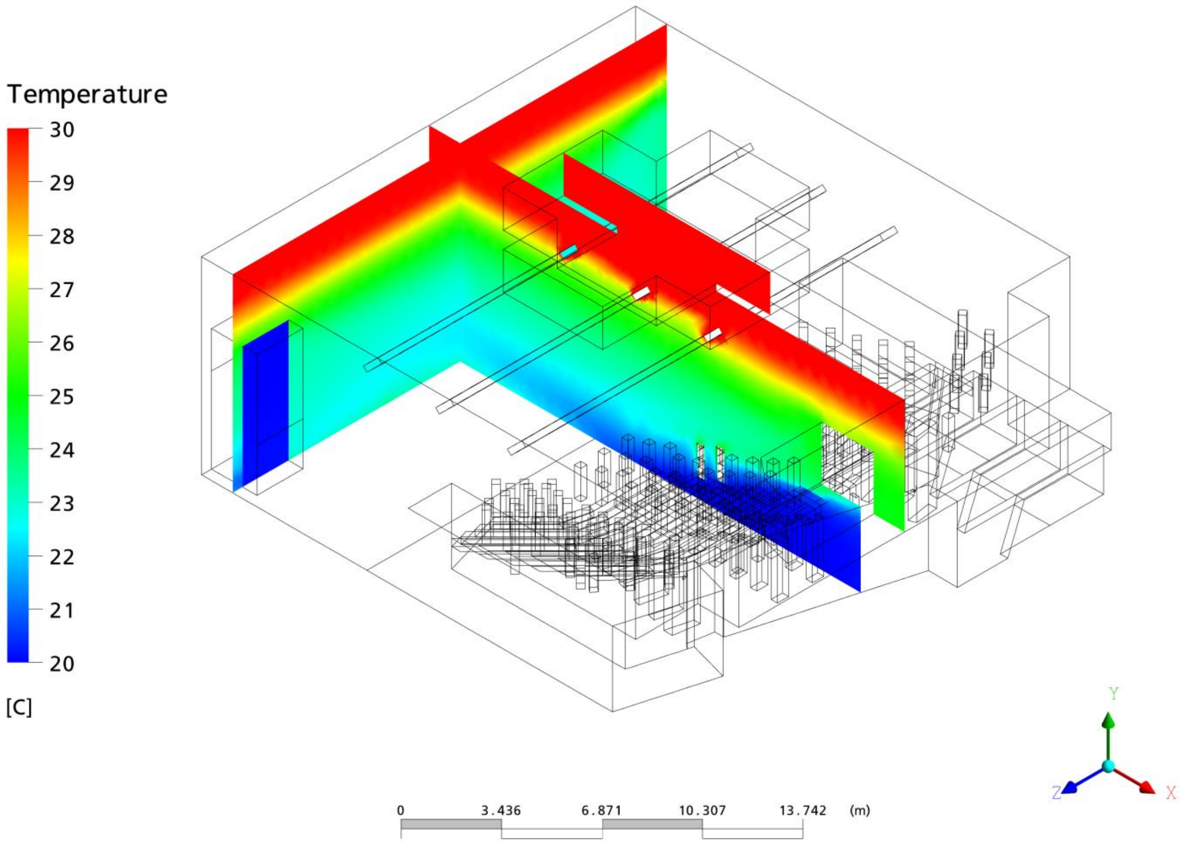
Dr Paul Cropper

De Montfort University

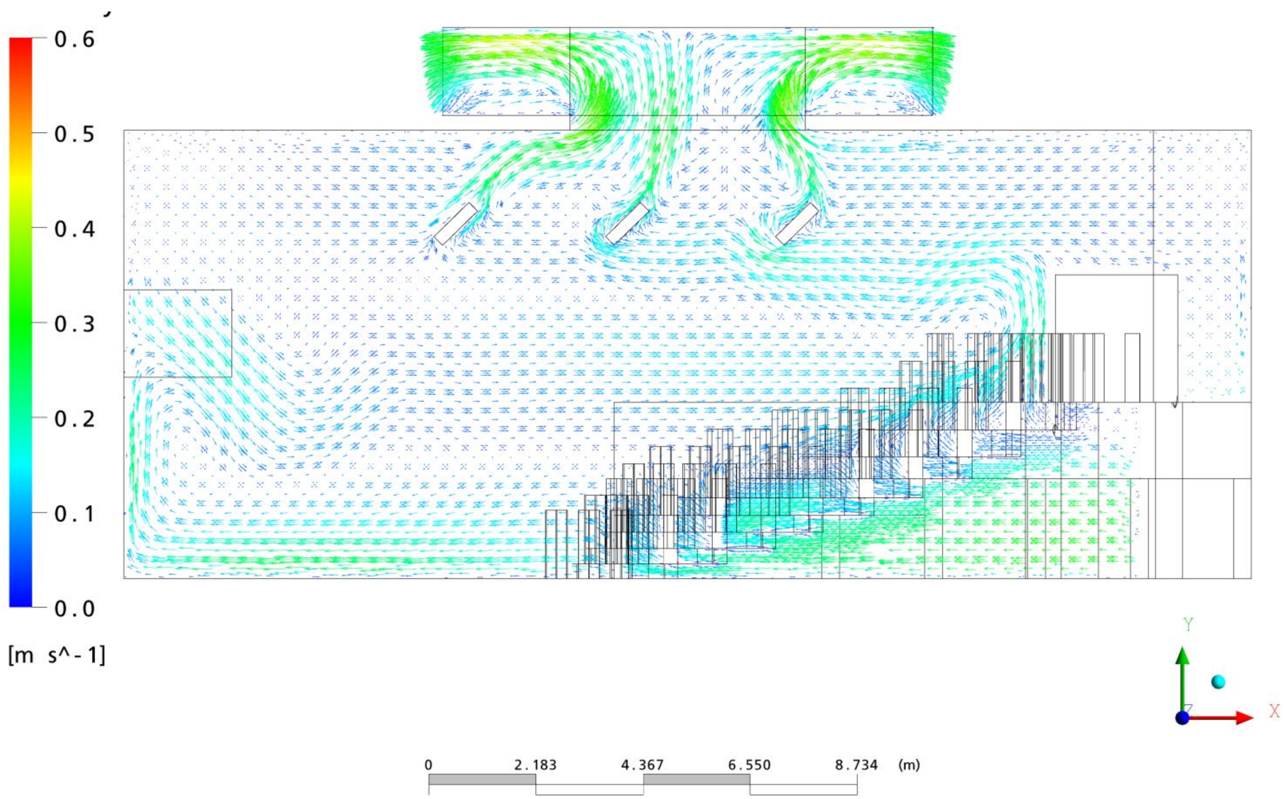
Research Project

- Funded by the UK Engineering and Physical Sciences Research Council (EPSRC)
- Collaborative project between De Montfort University and Loughborough University
- Other collaborators: ANSYS UK

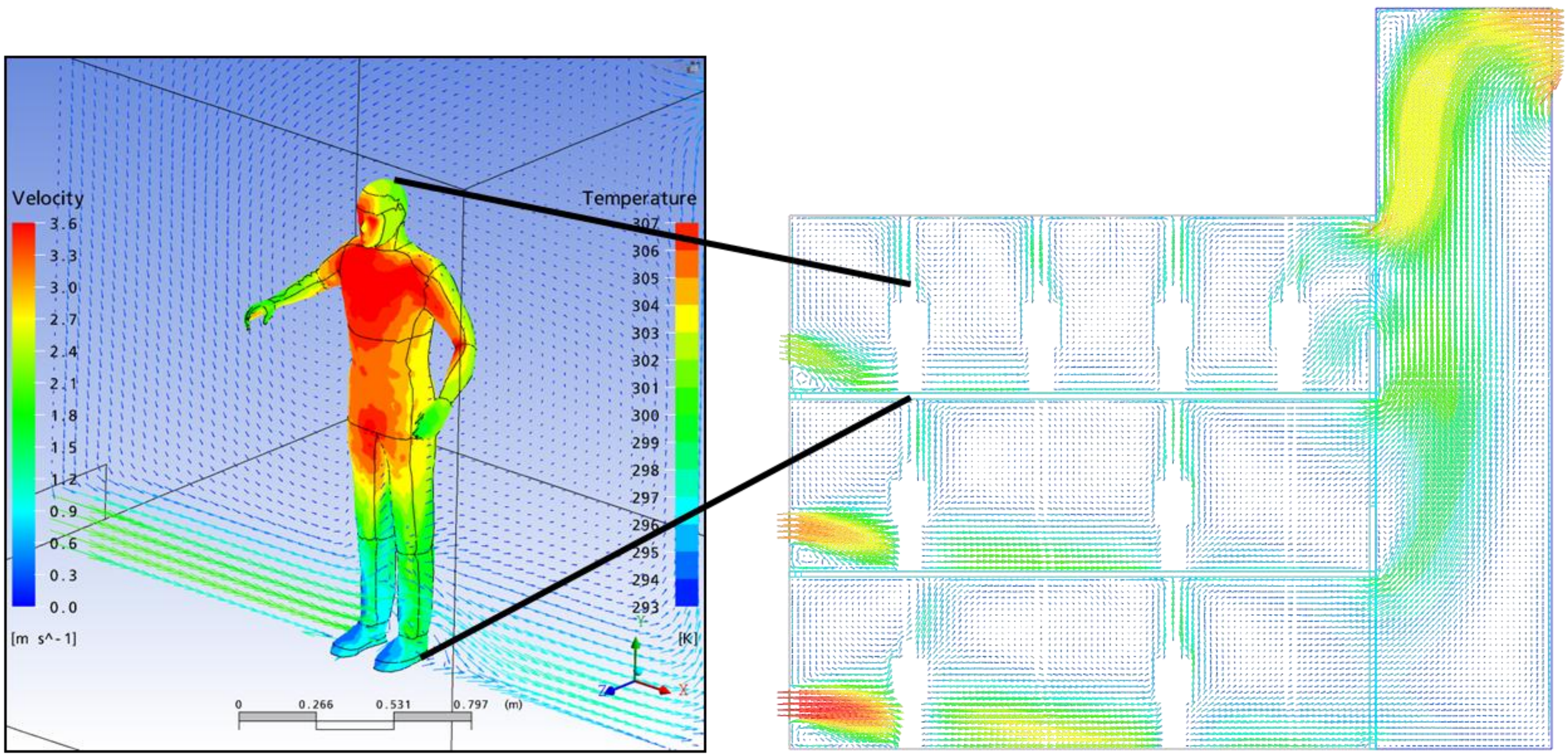
CFD – temperature distribution



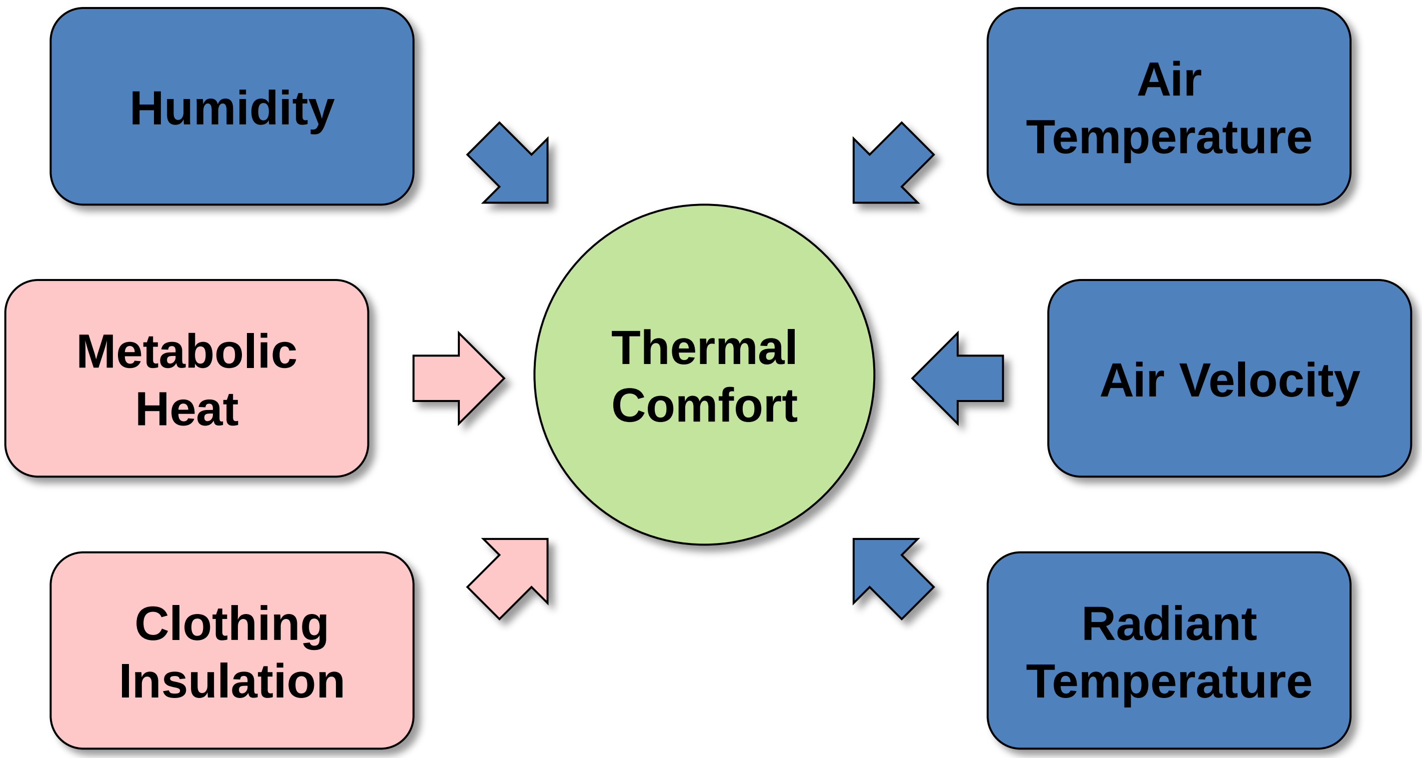
CFD – airflow distribution



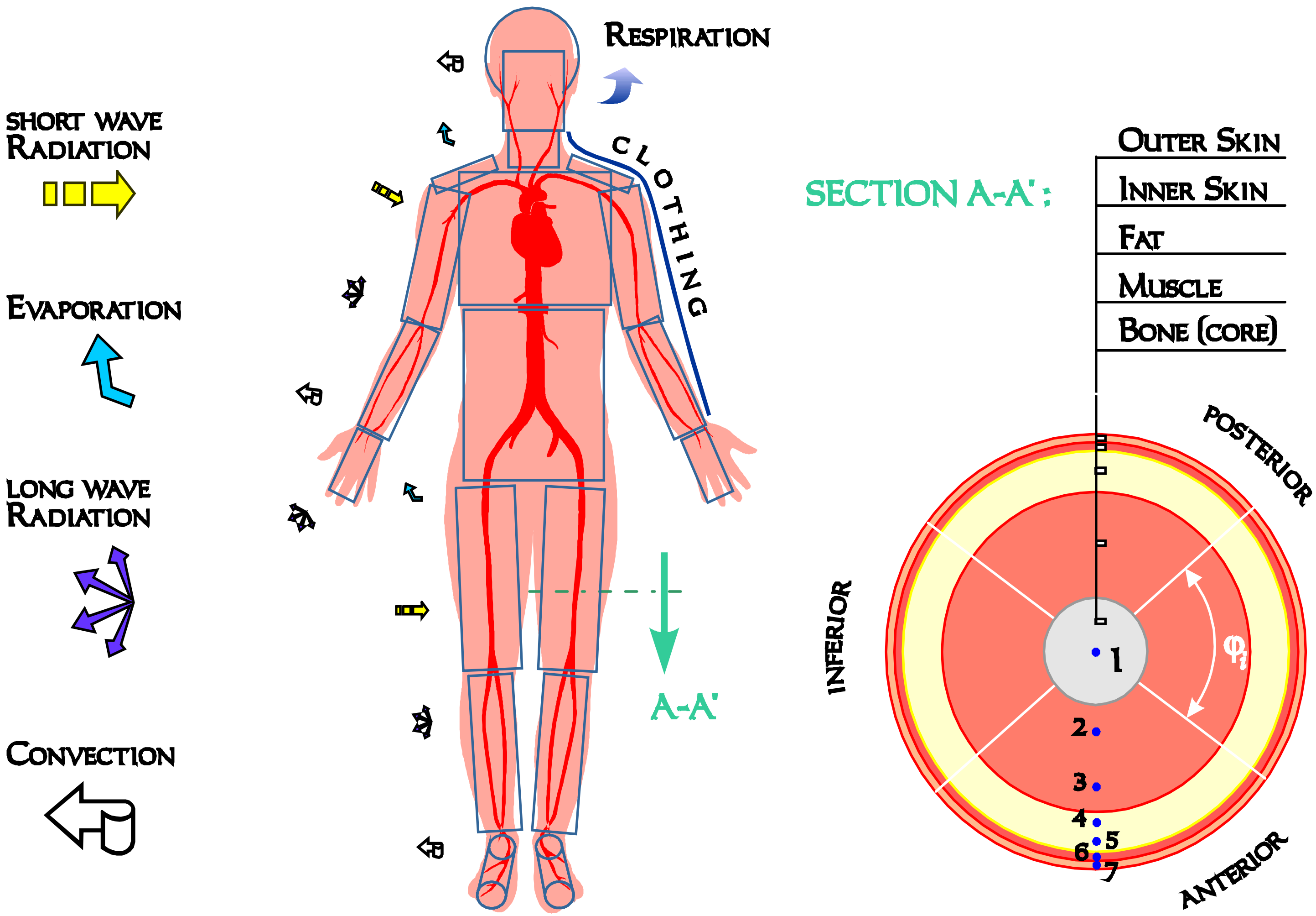
Modelling a human body in CFD



What is thermal comfort?

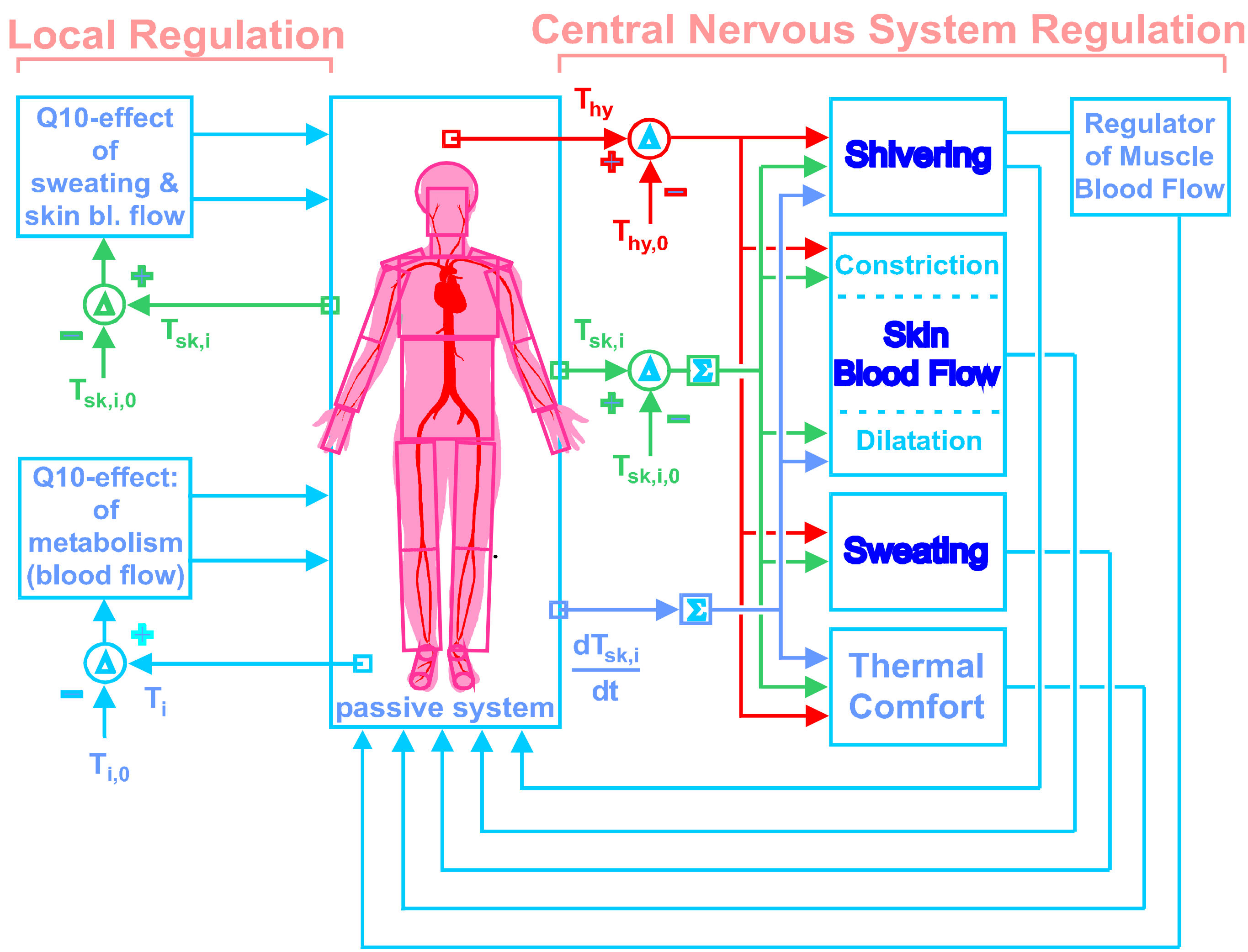


IESD-Fiala model - Passive System



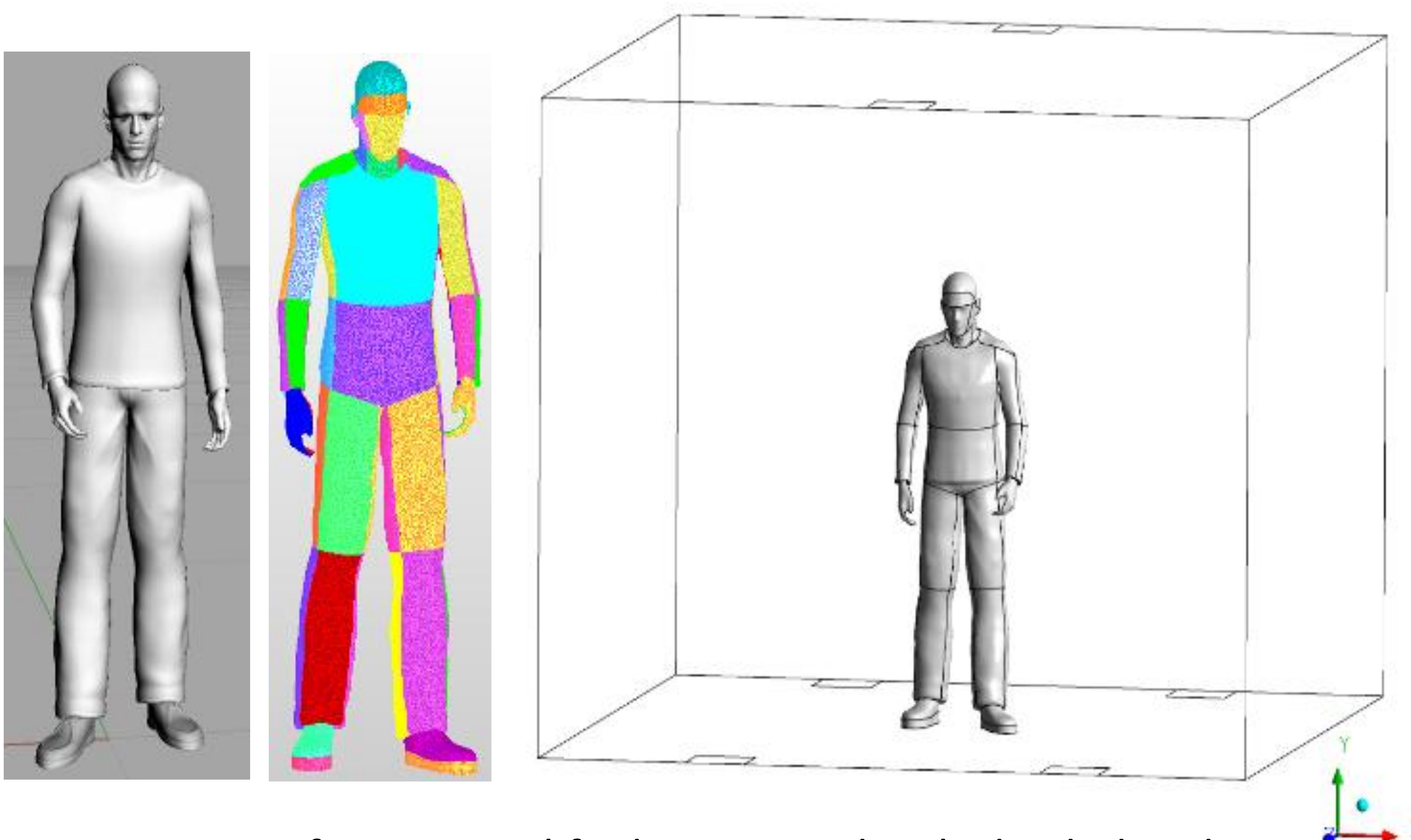
Source: Dr Dusan Fiala

IESD-Fiala model - Active System



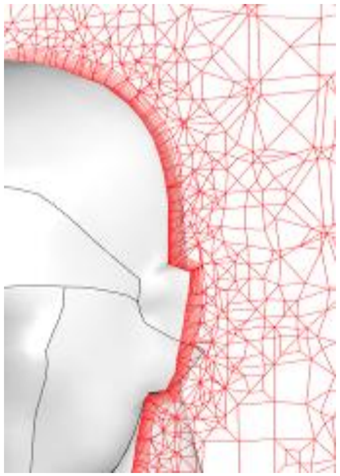
Source: Dr Dusan Fiala

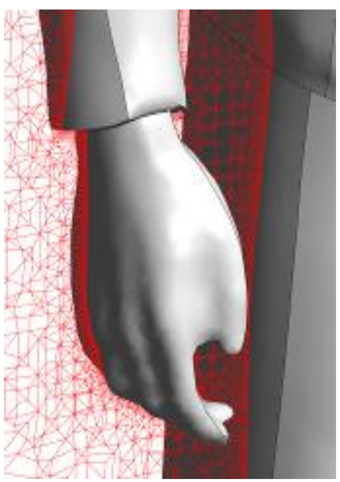
A human thermal manikin

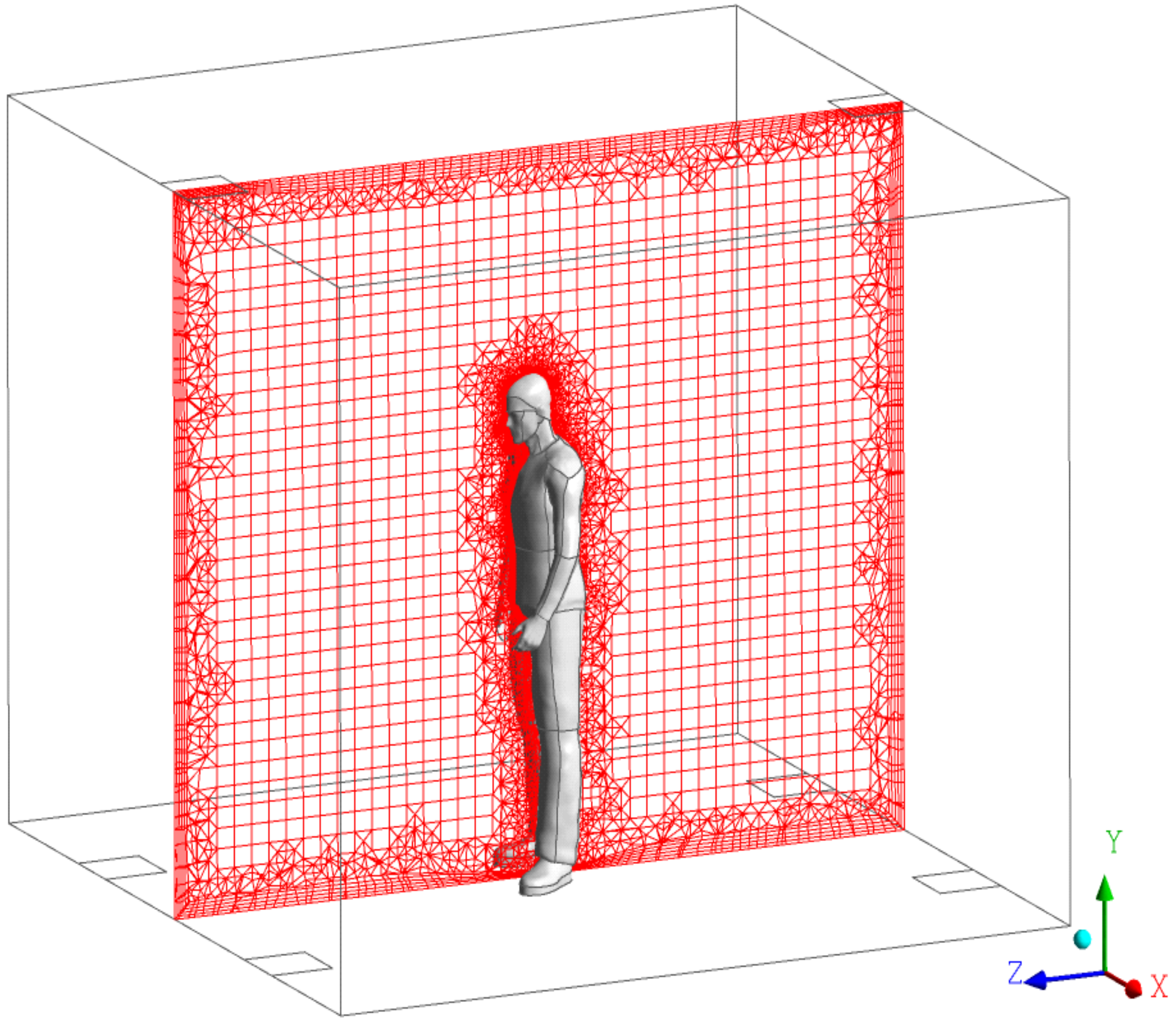


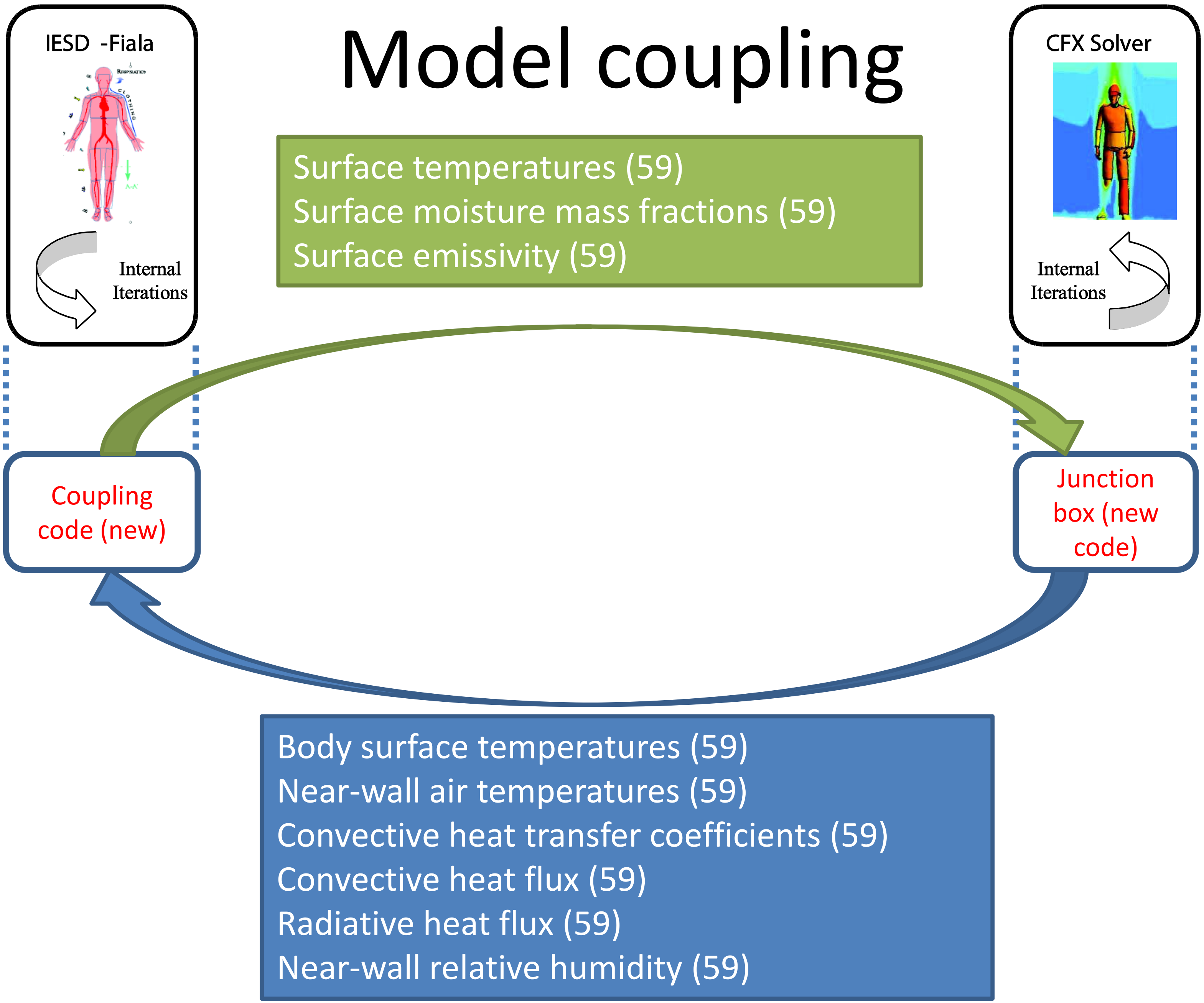
Human figure, simplified, optimised, sub-divided and placed in a CFD environment

The CFD mesh








Model coupling
IESD -Fiala
Internal Iterations
CFX Solver
Internal Iterations
Surface temperatures (59)
Surface moisture mass fractions (59)
Surface emissivity (59)
Coupling code (new)
Junction box (new code)
Body surface temperatures (59)
Near-wall air temperatures (59)
Convective heat transfer coefficients (59)
Convective heat flux (59)
Radiative heat flux (59)
Near-wall relative humidity (59)

Data exchange– CFX

For each patch, read

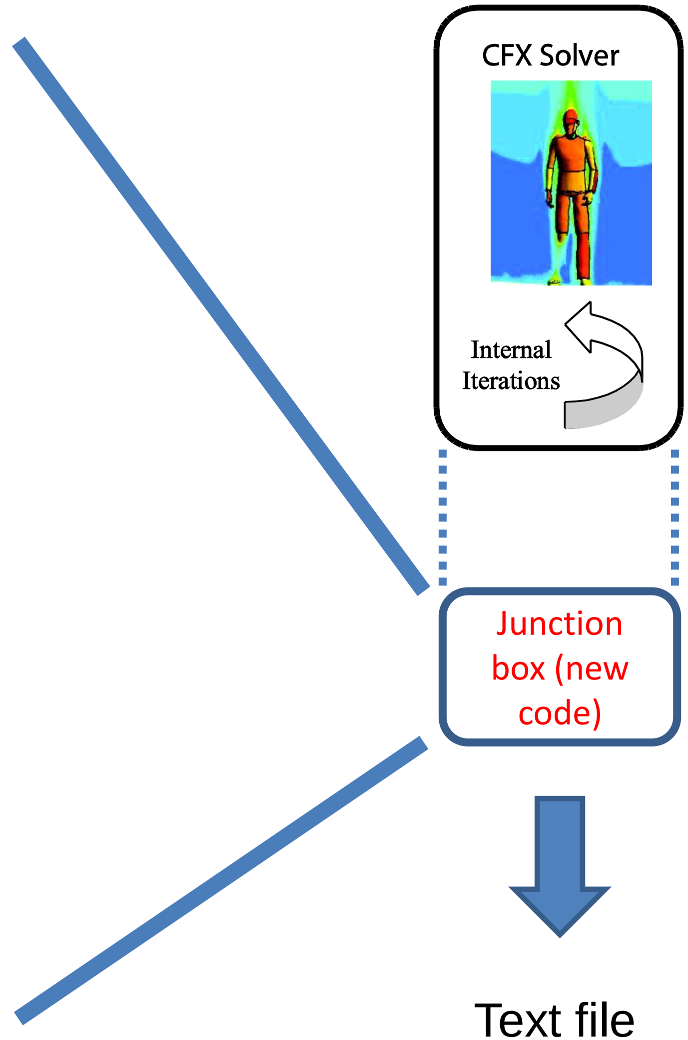
1. Area
2. Surface temperature (Tw)
3. Convective heat transfer coefficient (CHTC)
4. Near-wall water ideal gas mass fraction (Mf)
5. Total wall heat flux (Qw)
6. Radiative heat flux (Qr)

Calculate:

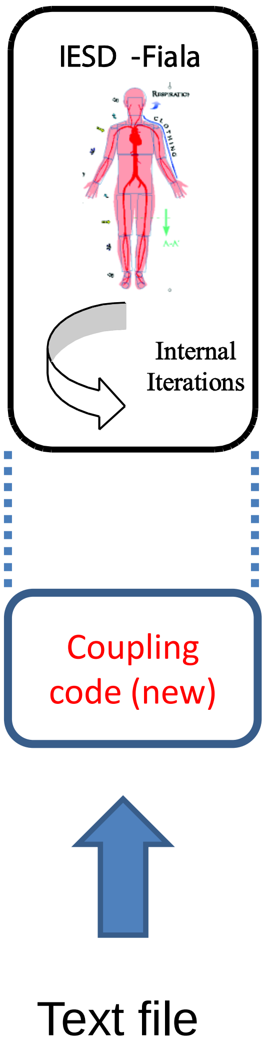
1. $Qc = Qw - Qr$
2. $Rh\_nw = Psg/Pss \times 100$
3. $Tnw = Tw - Qc/CHTC$
4. $Qc = Qc \times Area$
5. $Qr = Qr \times Area$

(area correction for patch area difference)

Where:
Pss = Saturated vapour pressure (from Mf and Tnw)
Psg = Vapour pressure of water vapour mixed with dry air (from Tnw)



Data exchange – IESD-Fiala model



Read text file from CFX

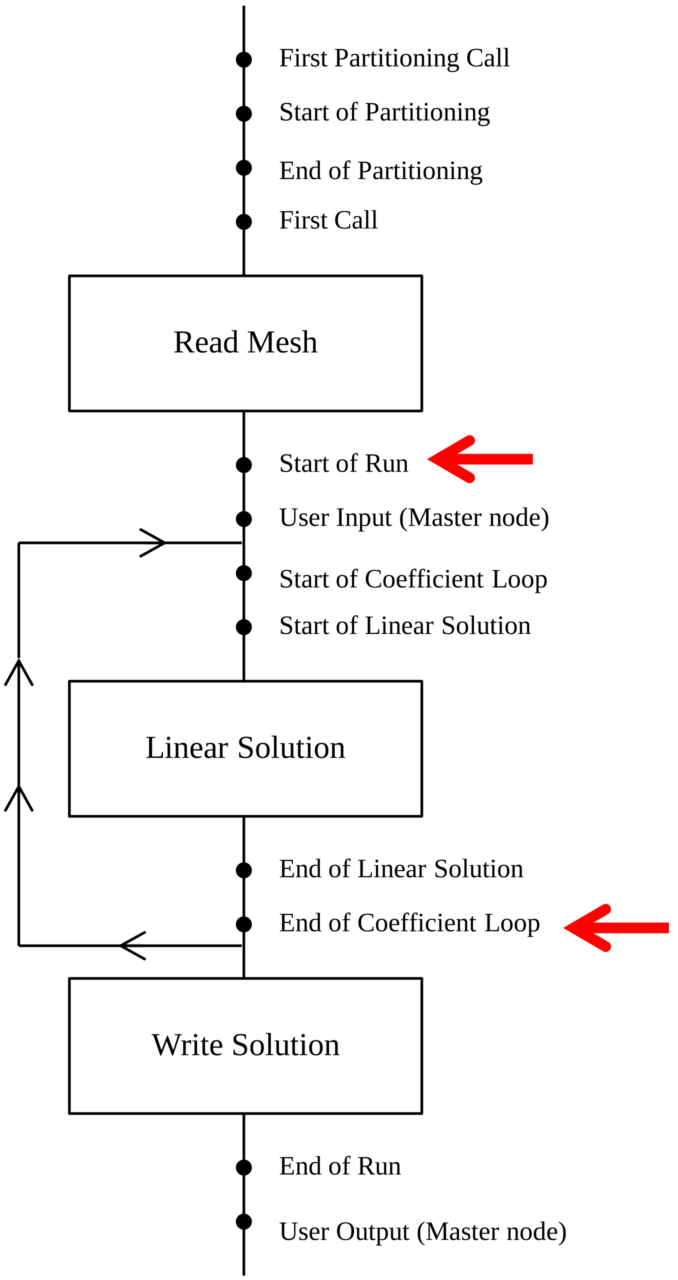
Calculate:
1. Qc/area x clothing factor
2. Qr/area x clothing factor

(area correction for patch area difference and for clothing)

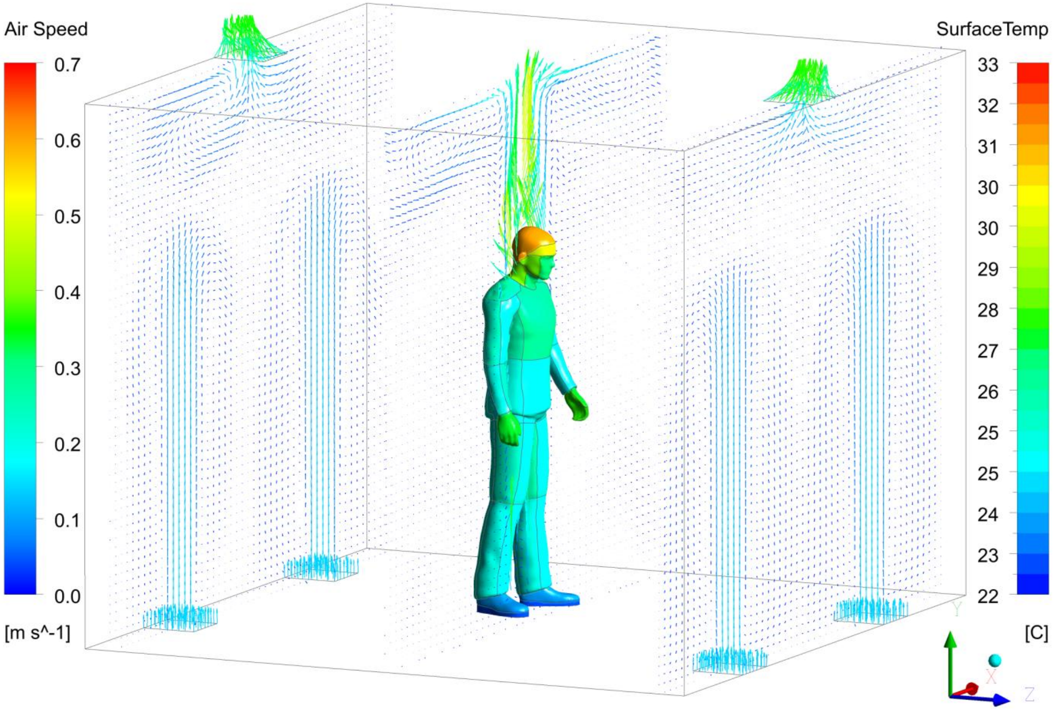
Pass to IESD-Fiala model (for each patch):
1. Near-wall relative humidity
2. CHTC
3. Tnw
4. Qc
5. Qr (long wave)

Solver customisation

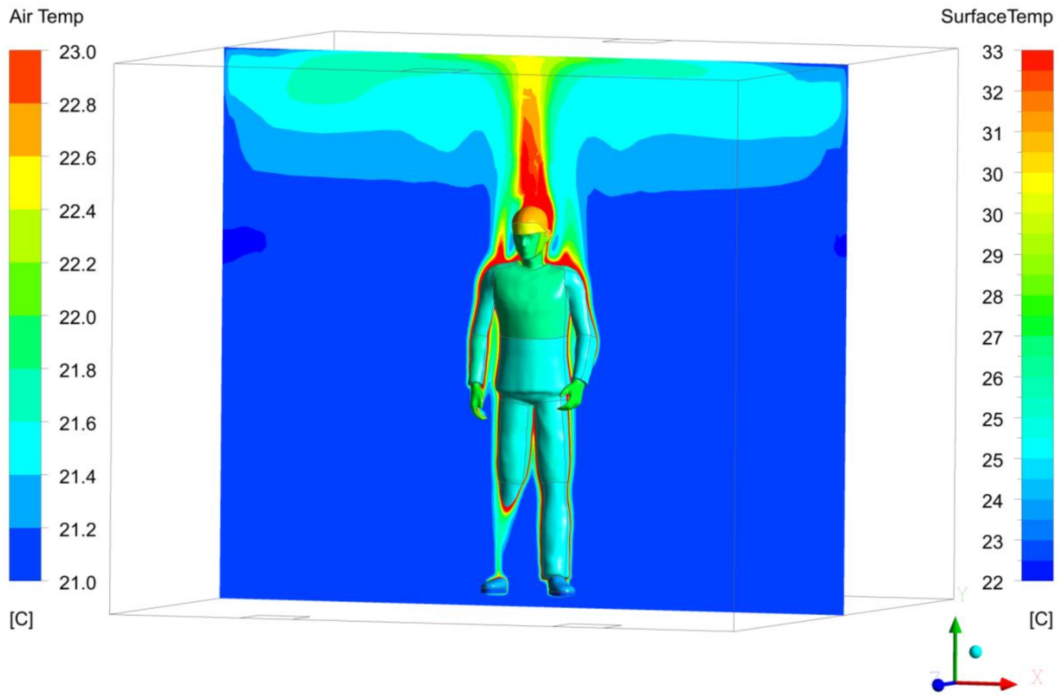
- Chosen CFD solver is ANSYS CFX
- All data is accessed using utility routines
- Junction Box code called at specific points in the execution cycle
- CEL functions replace fixed values



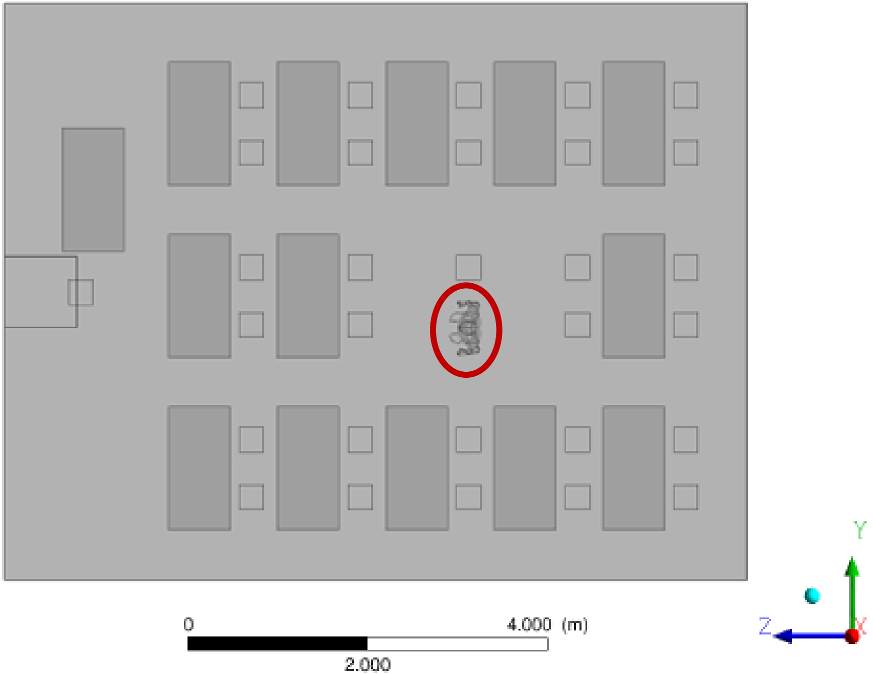
Air velocity and surface temperature

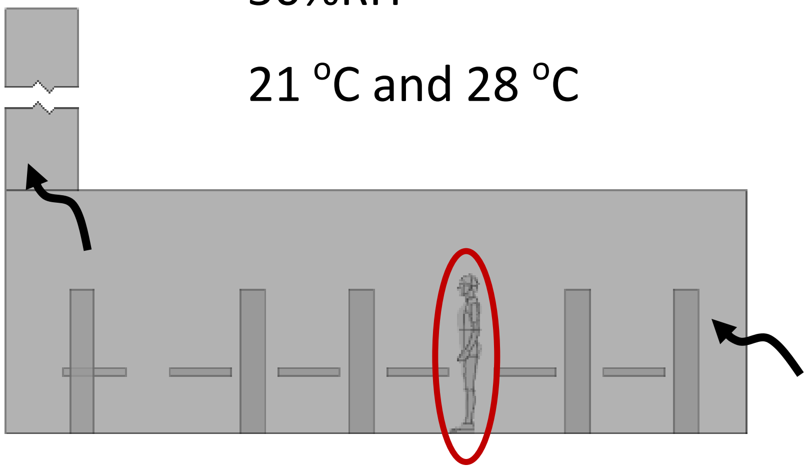


Air and surface temperatures



Example application





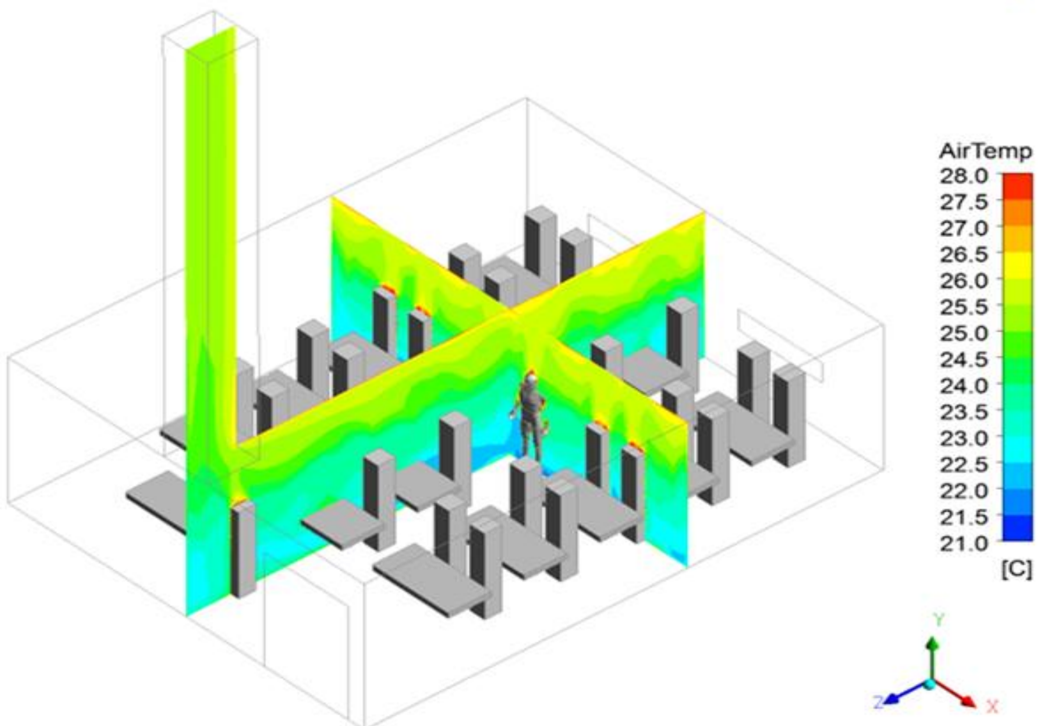
53m^2 classroom

31 occupants

50%RH

21 ^{o}C and 28 ^{o}C

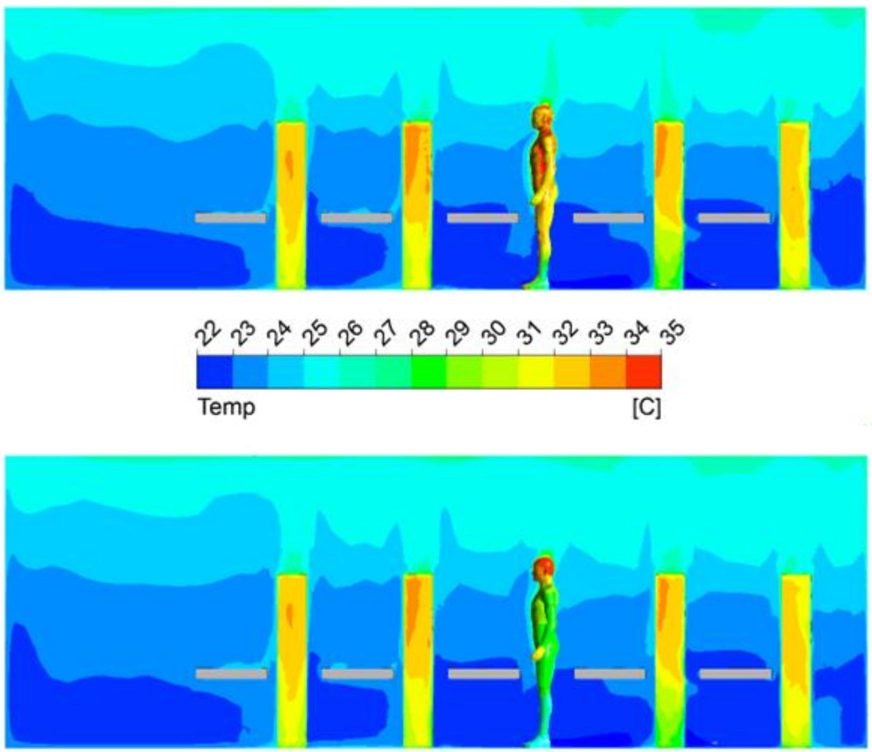
Air temperature distribution



21 ^{o}C case

~10 ac/h

Body surface and air temperature

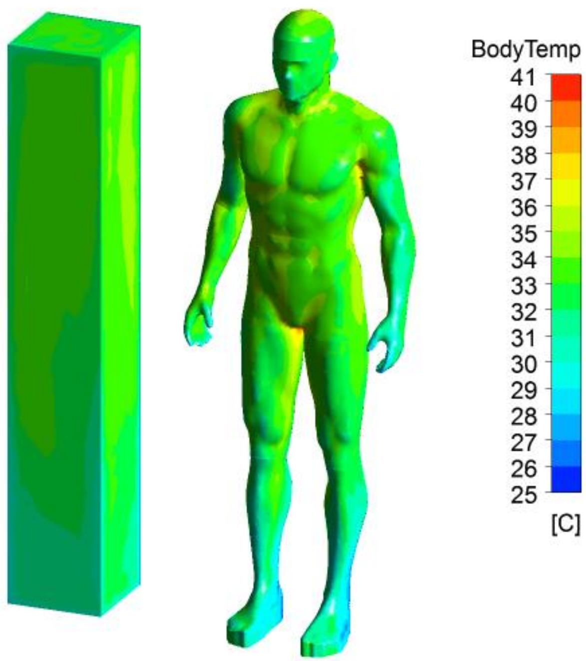


Uncoupled

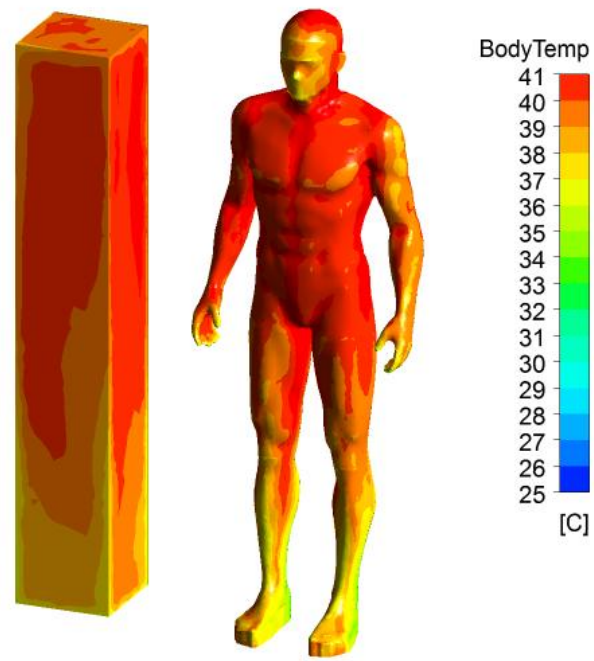
90W / person

Coupled

Influence of ambient temperature

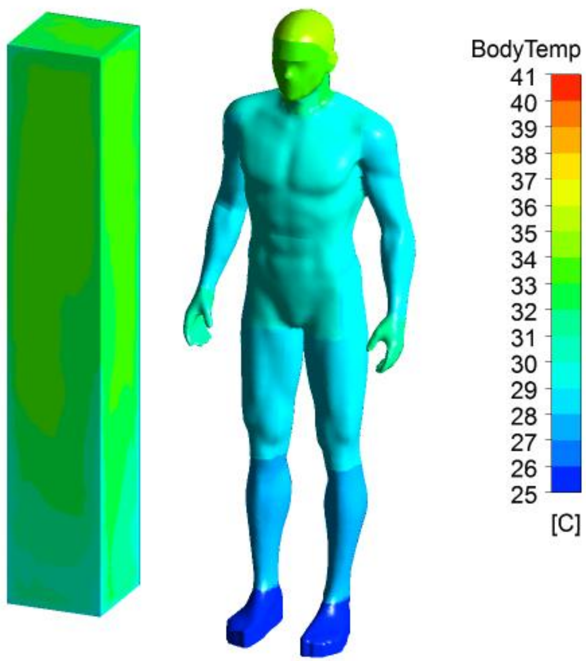


Uncoupled 21 ^{o}C case

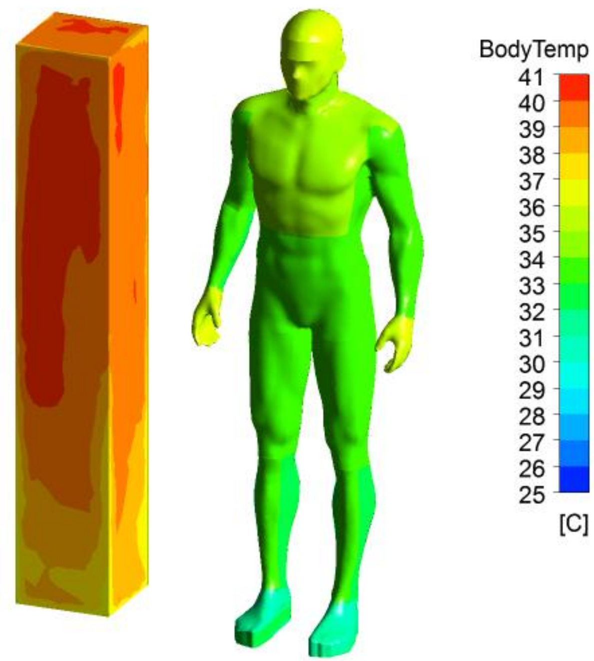


Uncoupled 28 ^{o}C case

Influence of ambient temperature



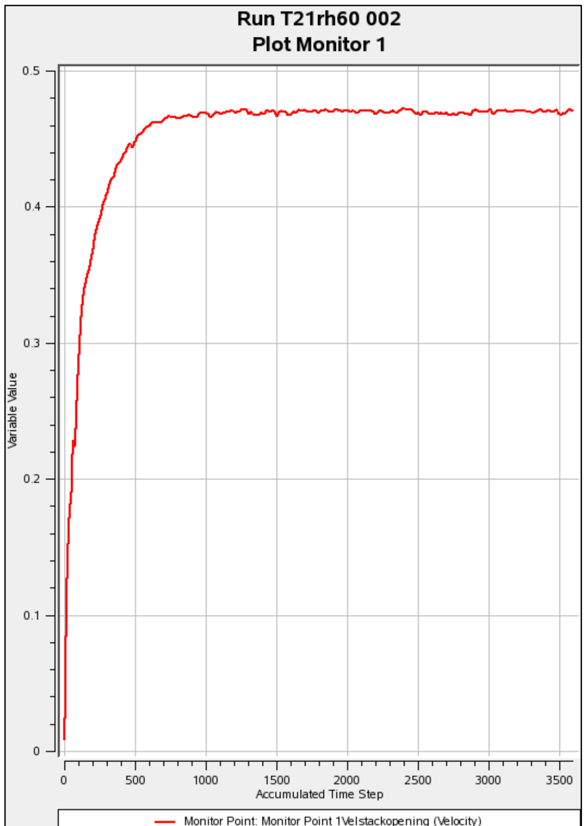
Coupled 21 ^{o}C case



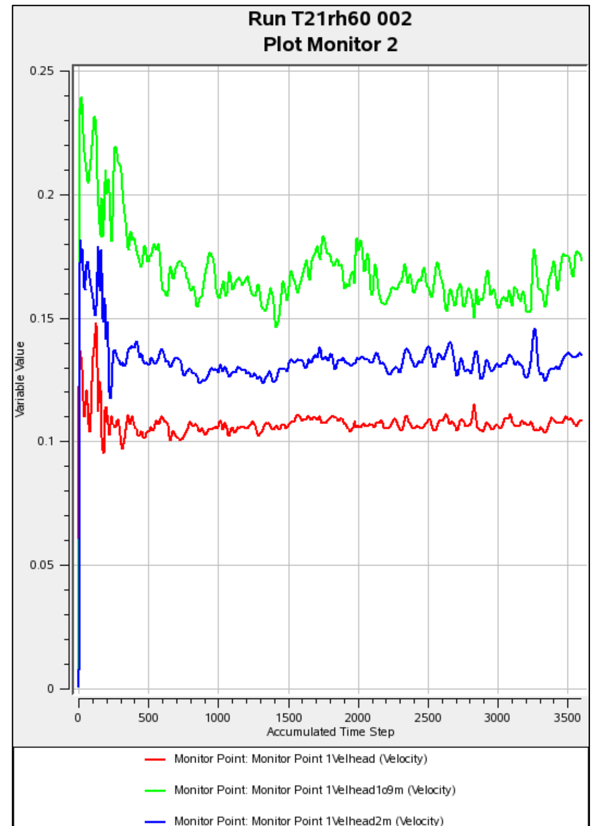
Coupled 28 ^{o}C case

Transient flow evolution

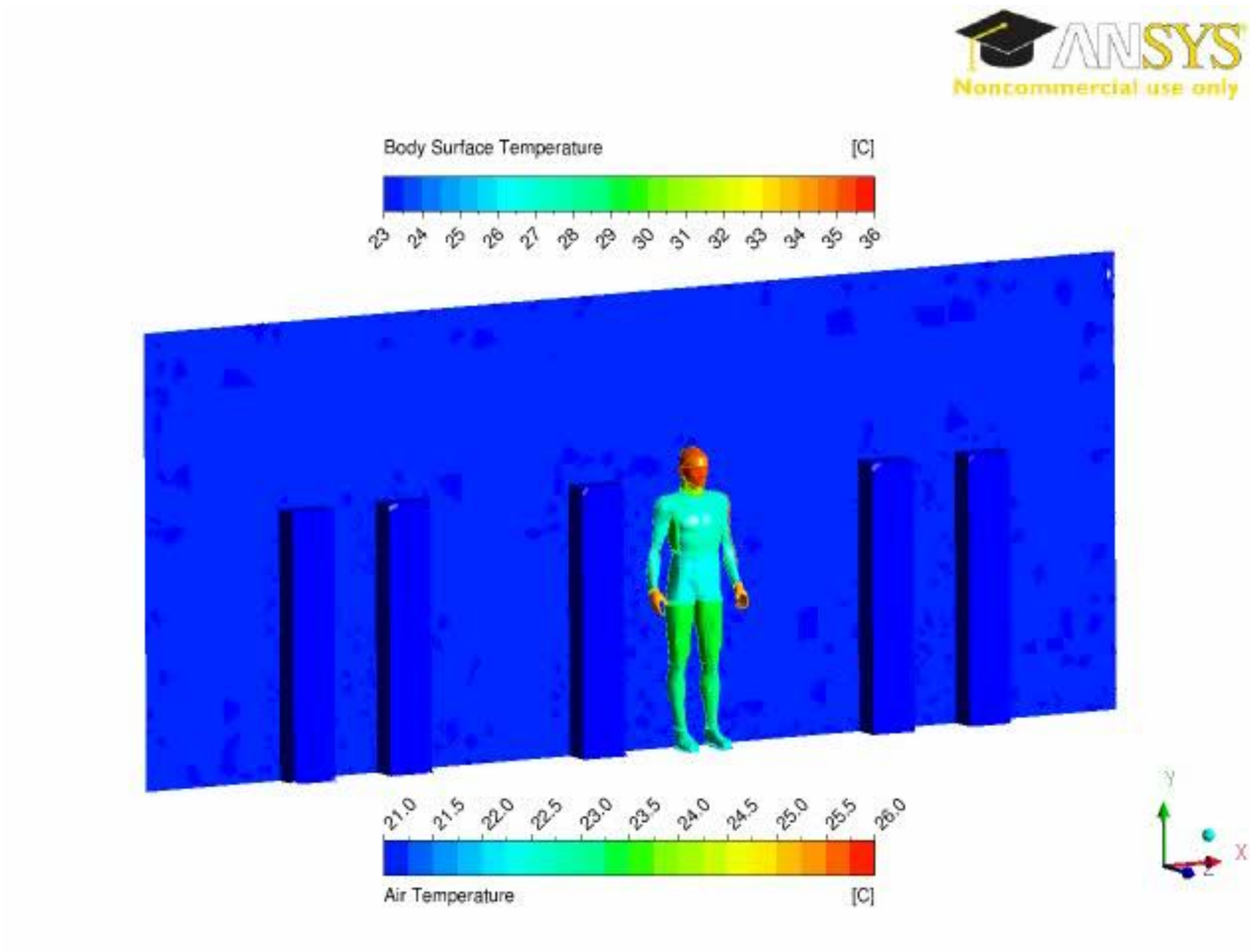
Stack velocity



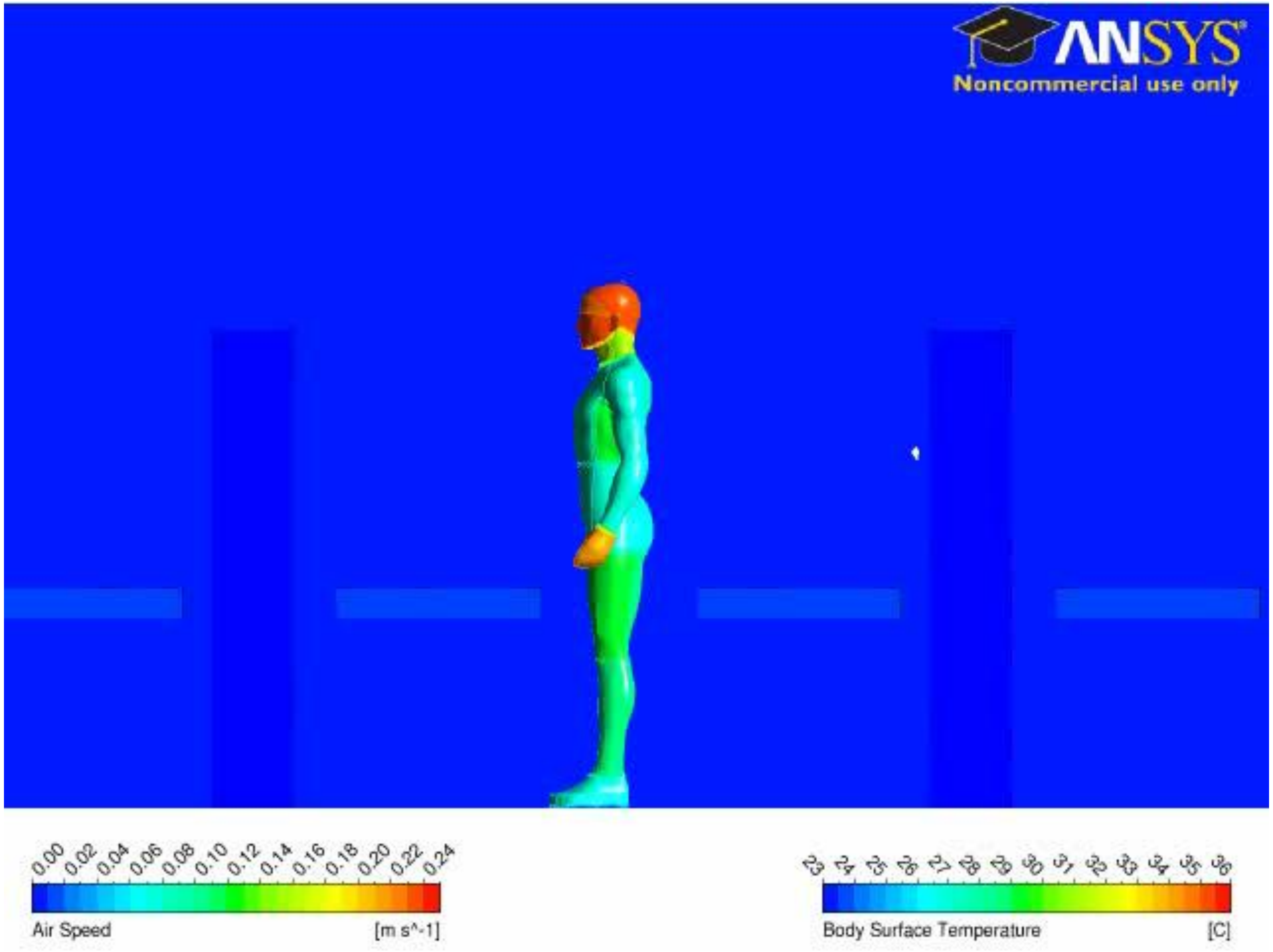
Velocity above head



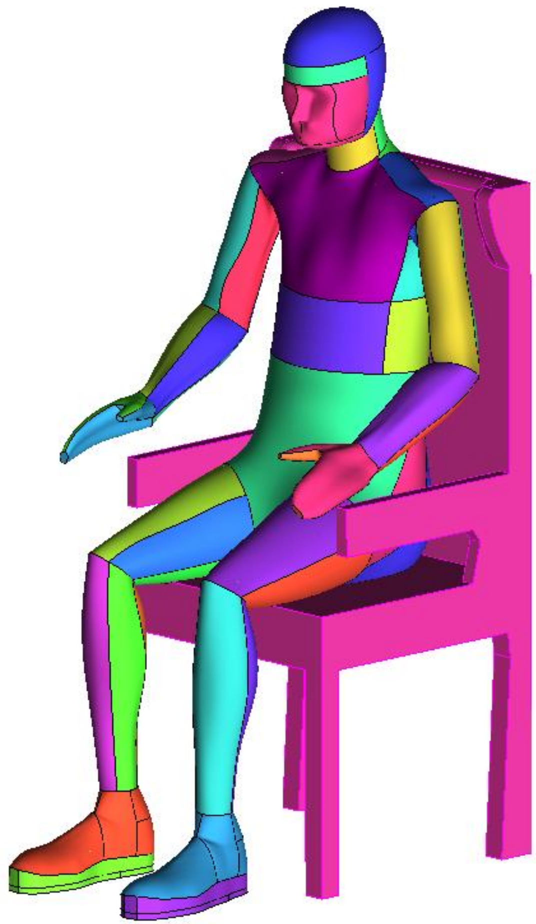
Transient – temperature evolution



Transient – velocity evolution

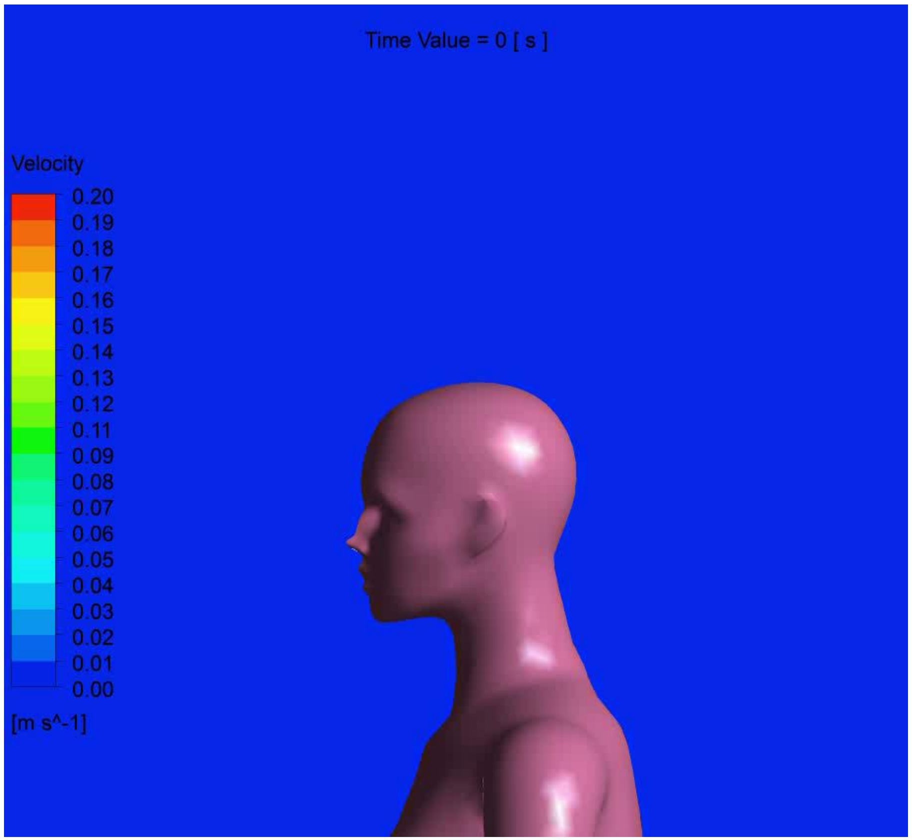


Seated thermal manikin



Manikin courtesy of: Sandeep Rao Bolineni
Fraunhofer-Institut for Building Physics IBP

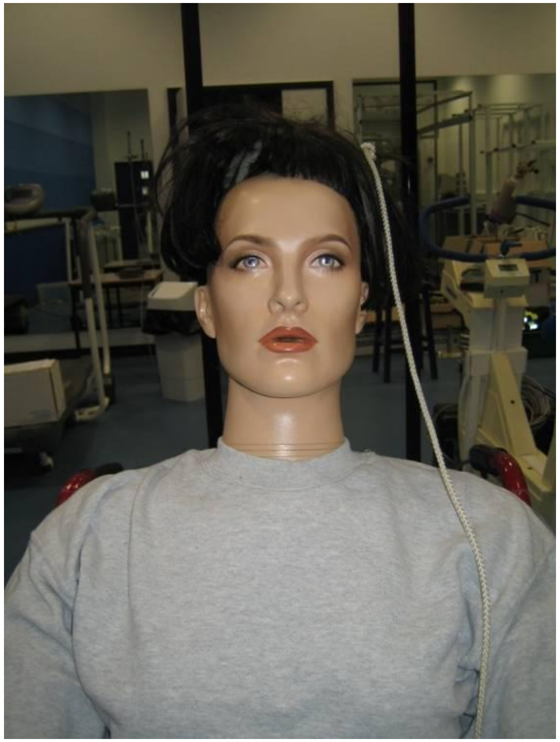
Breathing

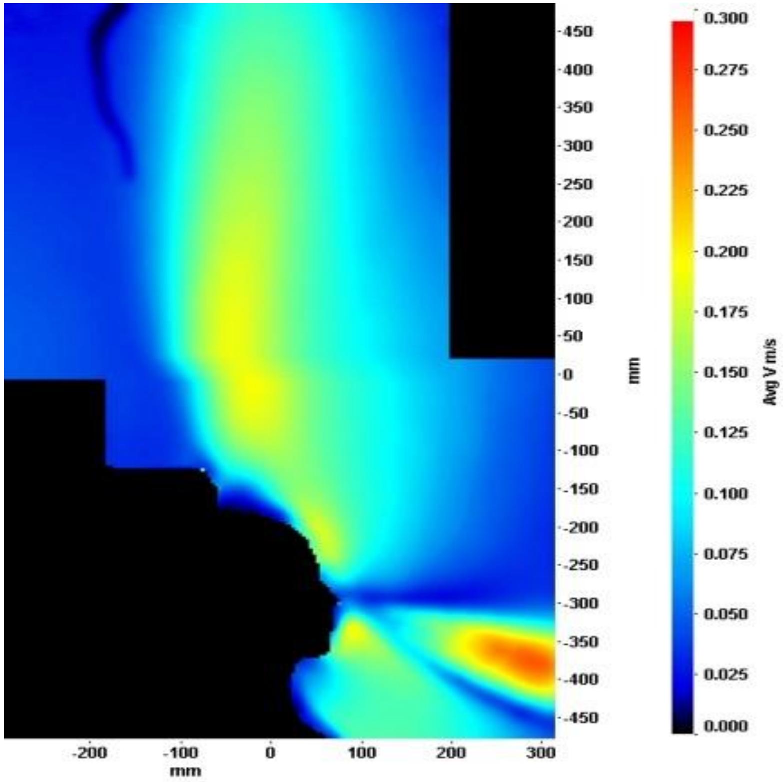


Source: Loughborough university

- CO_2 distribution and IAQ (e.g. schools)
- Person to person infection modelling (esp. healthcare buildings)

Empirical validation of breathing





Source: Loughborough university

Future Work

- Transient simulation – De Montfort University
- Breathing – Loughborough University
- New manikins – age, height, weight, gender
- New human physiology model
- Moving manikins – games technology
- Better clothing models
- Visualisation – 3D TV, VR, Holography

Questions?