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Modelling Approaches to Natural and Mixed-Mode Ventilation

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Natural and Mixed-Mode Ventilation Modelling
Building Simulation Group
UCL
24 May 2010

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What's special about natural ventilation?

- What sets it aside from mechanical ventilation ?
 - Smaller driving forces
 - Driving forces are less clearly understood and are not constant
 - ... and thus more challenging to predict
 - NV often inextricably linked to architectural form and fabric
 - ... thus attention to both architectural and services issues
- Why model?
 - Commercial
 - Client request
 - Compliance
 - Communication
 - Competition bids
 - Scientific
 - Uncertainty re. driving forces
 - New, innovative strategies
 - Dynamic behaviour
 - Non-linear behaviour

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Coverage of Presentation

- Concept design methods
- Analytical methods
- Dynamic thermal simulation
- Computational Fluid Dynamics
- Application example

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Concept design

Psychrometric chart with comfort envelope

London

Hong Kong

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Concept design

Psychrometric chart with operating modes

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Concept design: simplified equations

- See paper by Lomas (2007), Energy and Buildings
Architectural design of an advanced naturally ventilated building form
- Relatively straightforward equations can be used:

Heat gain

$$q(\text{m}^3/\text{s}) = \frac{QA}{\rho C_p \Delta T}$$

Floor area

Flow rate

$$\text{free opening area, } A(\text{m}^2) = \frac{q}{v}$$

Assumed air velocity
- ... to give useful concept design advice:


Lightwell x-sect

$$A_{LW} = \frac{Q}{v \rho C_p \Delta T}$$

Total floor x-sect

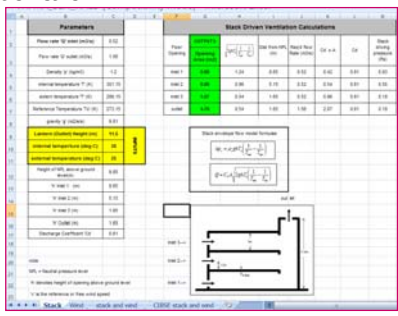
$$A_{total}$$

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Analytical methods

- Stack-calc



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Dynamic Thermal and Computational Fluid Dynamics

What vs how:

- DTS and CFD both predict thermal and ventilation performance
- DTS – whole building for a whole year ~ coarse spatial resolution
- CFD – key spaces for a point in time ~ fine spatial resolution

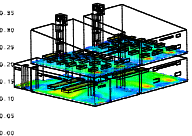
DTS

WHAT


CFD

HOW

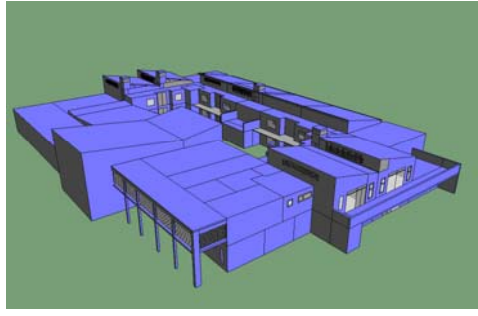
Speed (m/s)




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Dynamic thermal simulation model

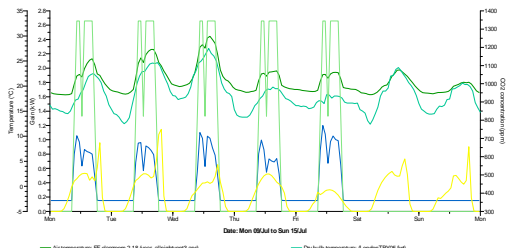


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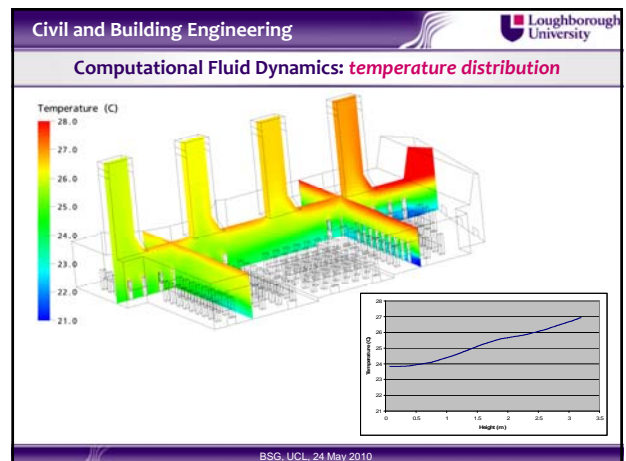
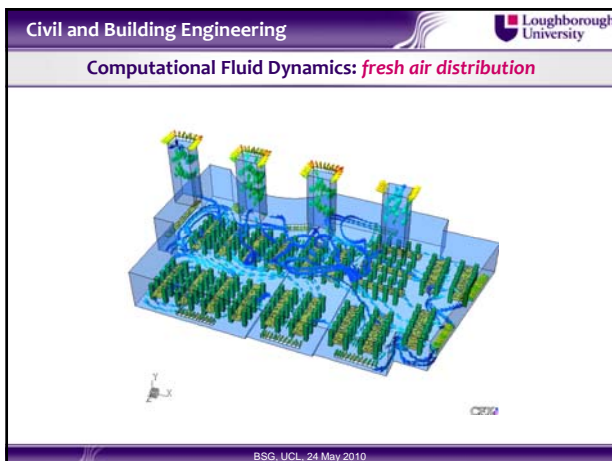
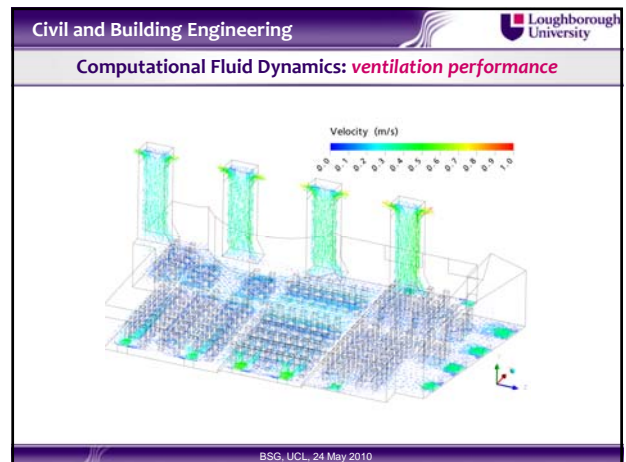
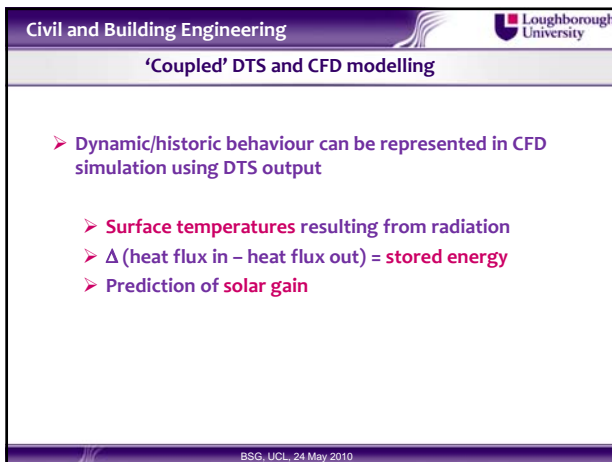
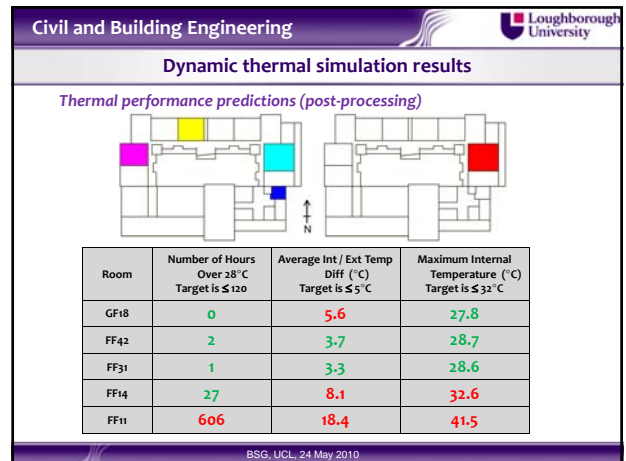
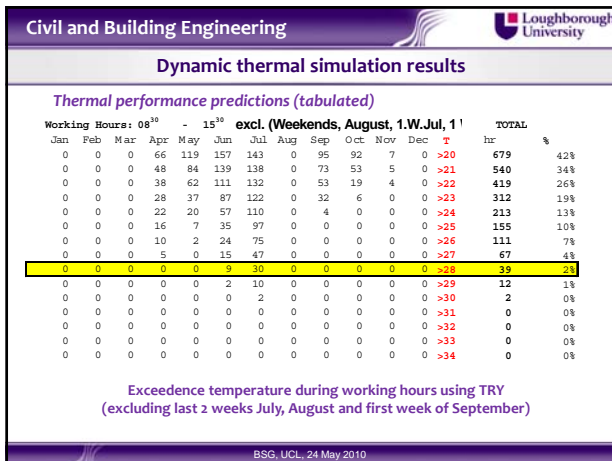
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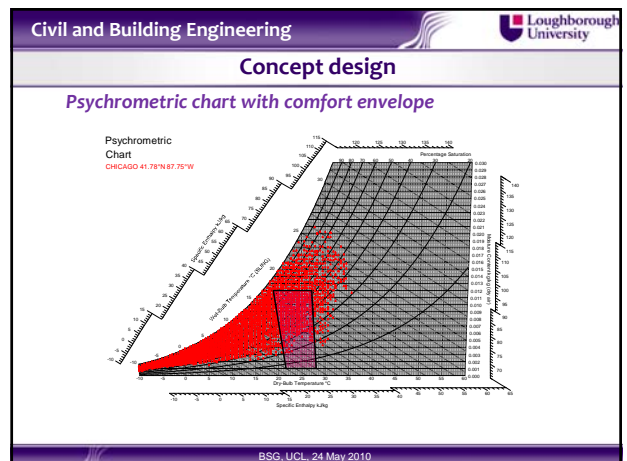
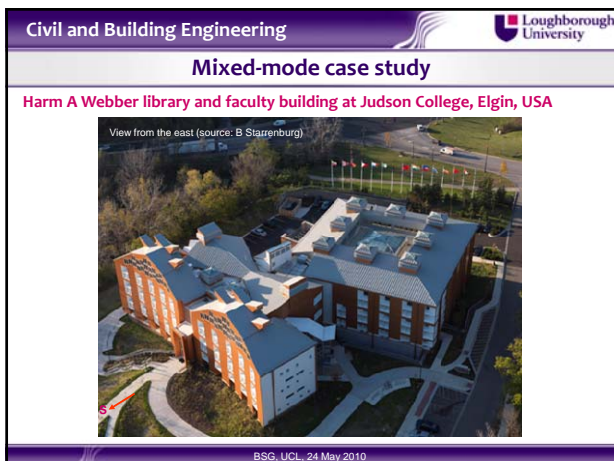
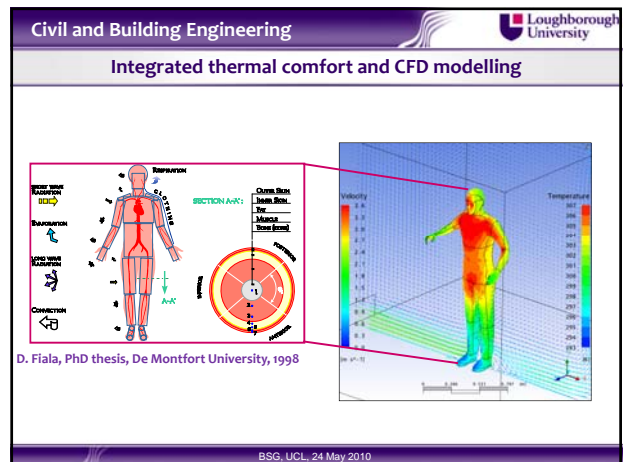
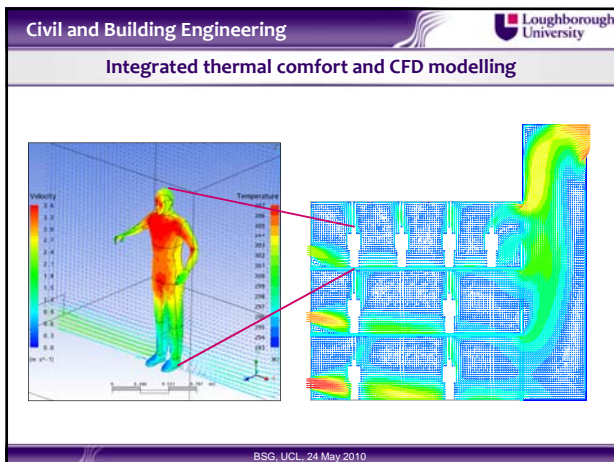
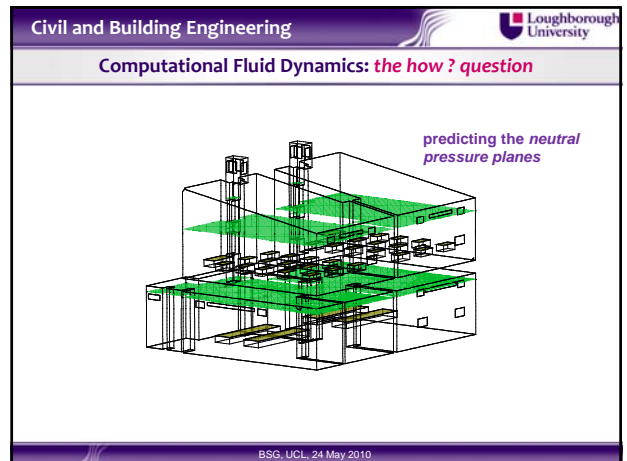
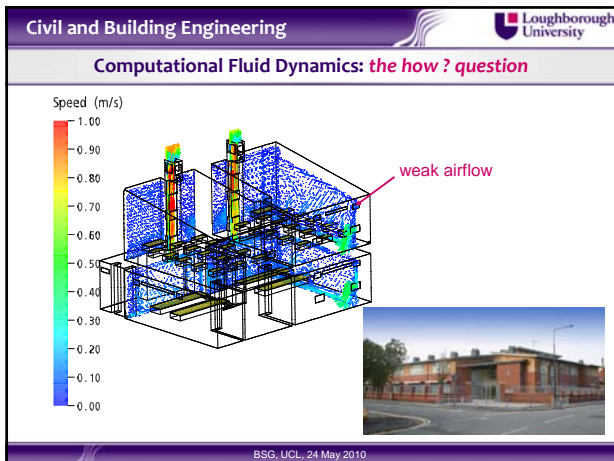
Dynamic thermal simulation results


Thermal performance predictions (graphical)



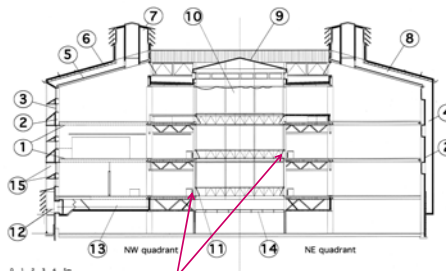
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$$\frac{A_{LW}}{A_{total}} = \frac{Q}{v\rho C_p \Delta T}$$

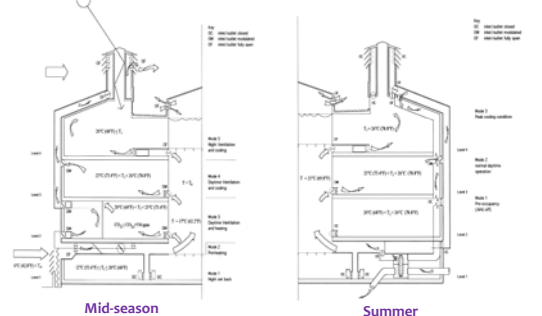
Source: Short and Lomas, Building Research and Information, 2007

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Judson college: operating modes

Source: Short and Lomas, Building Research and Information, 2007



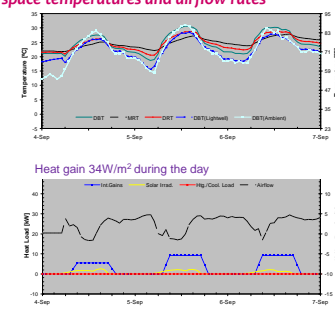
Mid-season Summer

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Judson college: Passive ventilation mode

Predicted space temperatures and airflow rates



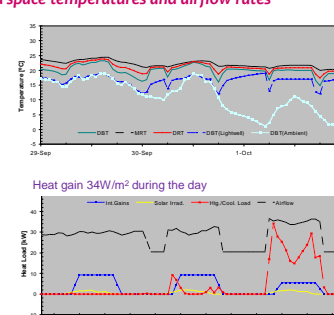
Heat gain 34W/m² during the day

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Judson college: Passive ventilation and heating mode

Predicted space temperatures and airflow rates



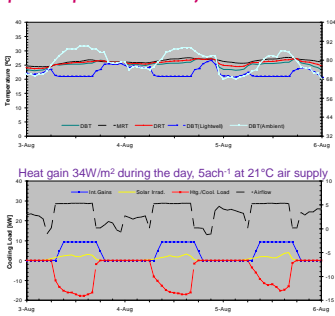
Heat gain 34W/m² during the day

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Judson college: Mechanical ventilation and cooling mode

Predicted space temperatures and airflow rates



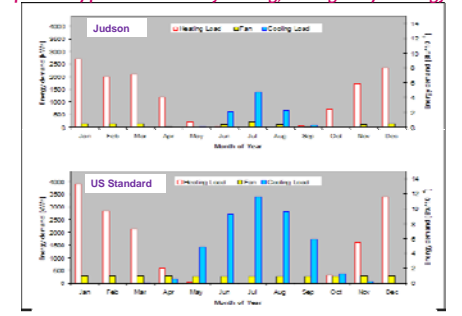
Heat gain 34W/m² during the day, 5ach¹ at 21°C air supply

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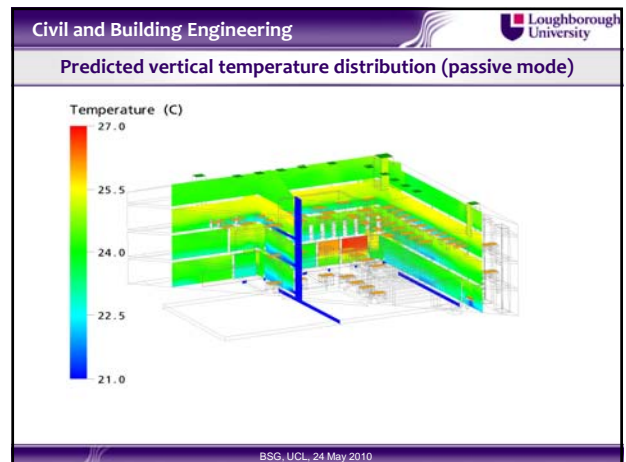
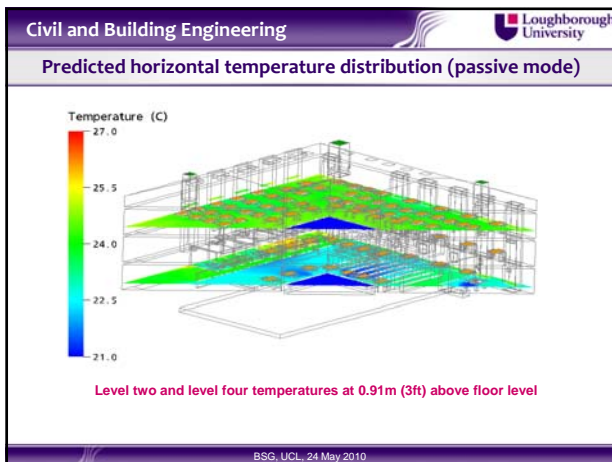
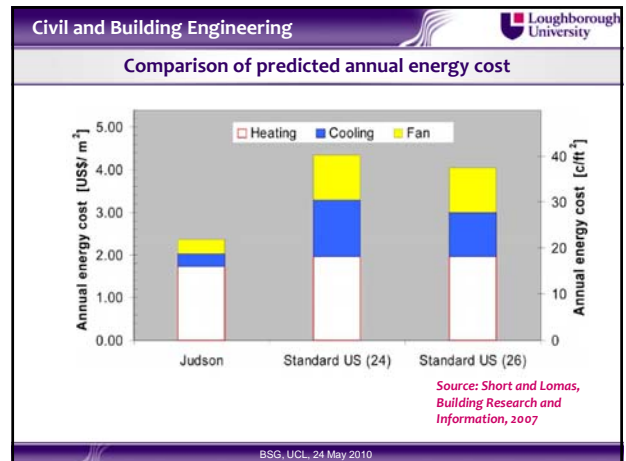
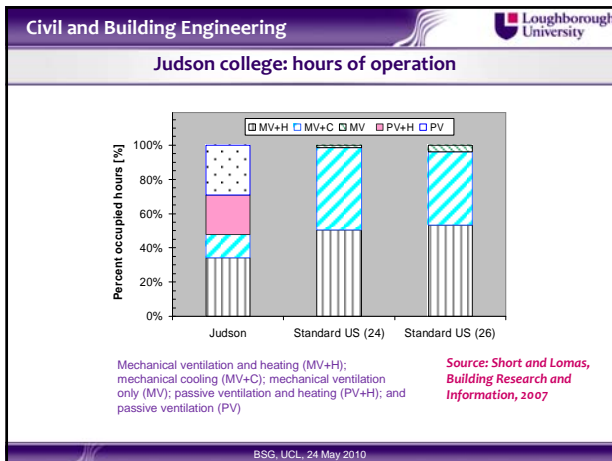
Judson college: Energy predictions


Comparison of predicted monthly heating, cooling and fan energy loads



Source: Short and Lomas, Building Research and Information, 2007

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- ### The future
- More coupling of CFD and DTS programs ???
 - Simulation of control to optimise mixed-mode performance ???
 - Time dependent modelling using CFD ???
 - Solution multiplicity
 - Development and stability of ventilation flows
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