CONSULTING ENGINEERS & SCIENTISTS

Wind – Analogue or Digital?

CIBSE Building Simulation Group and Natural Ventilation Group
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Contents

About RWDI

About RWDI

- Headquarters in Guelph, Ontario
- Established in 1972
- 350+ employees

Project Experience

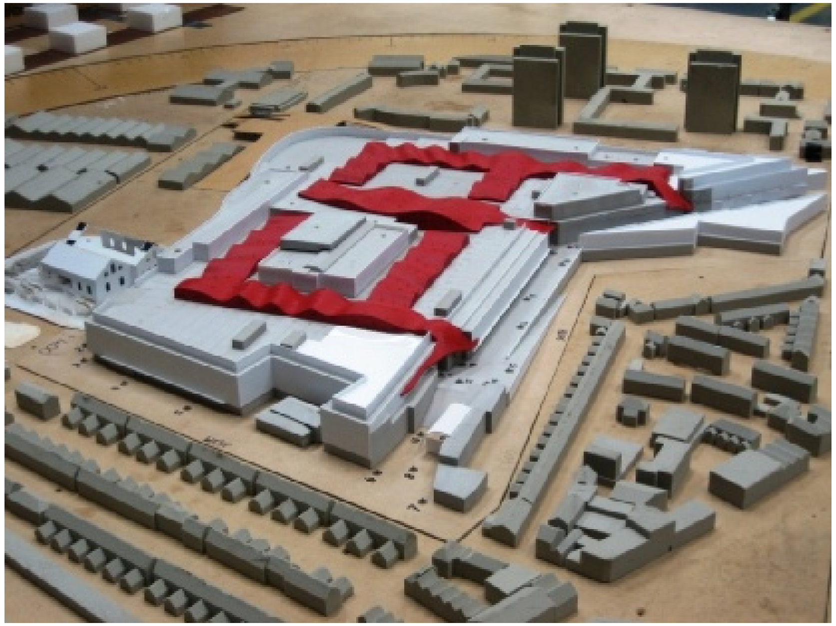
Office Locations

About RWDI – Our Activities

Structure
Masterplanning
Facades

External Spaces
Energy Consumption
Comfort
Internal Spaces

Concept Design



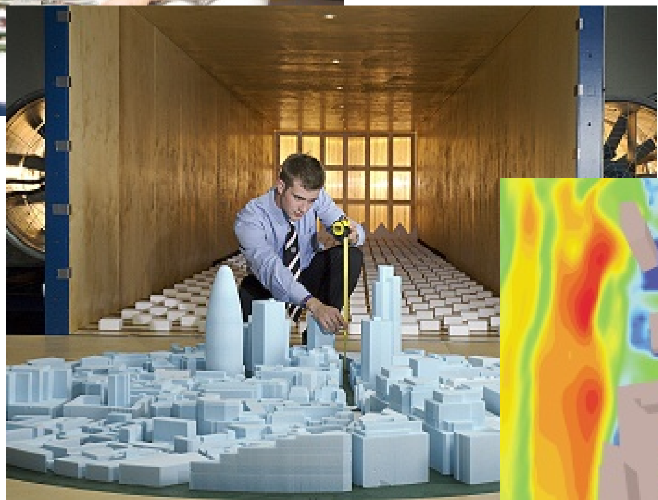
Detailed Design

Cladding Wind Loads
Pedestrian Comfort

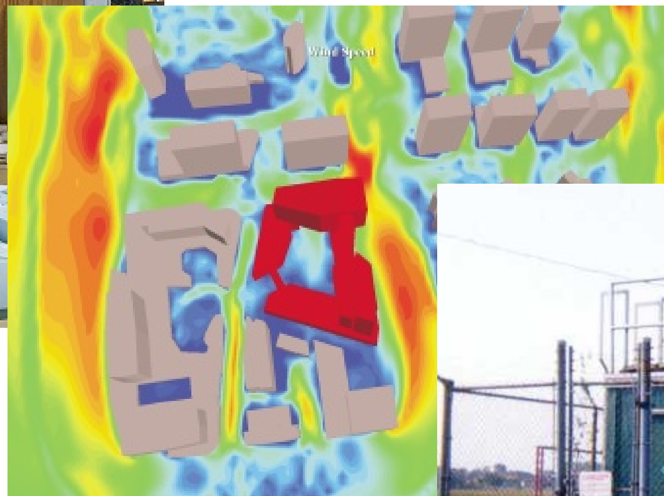
Structural Wind Loads
Exhaust Re-entrainment
Daylighting
Wind Pressure Ventilation
Sand and Dust Issues

Aeroacoustics
Snow and Ice Studies
Glare
Stack Effect
Rain Ingress Studies

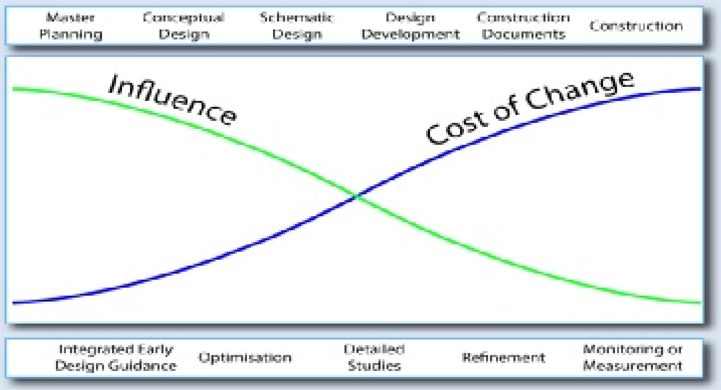
About RWDI… a selection of what we do …



- § Design Advice / Consultation
- § Physical Scale Modeling
  (Wind Tunnel / Water Flume)
- § Computer Modelling
- § On-site Monitoring & Measurement

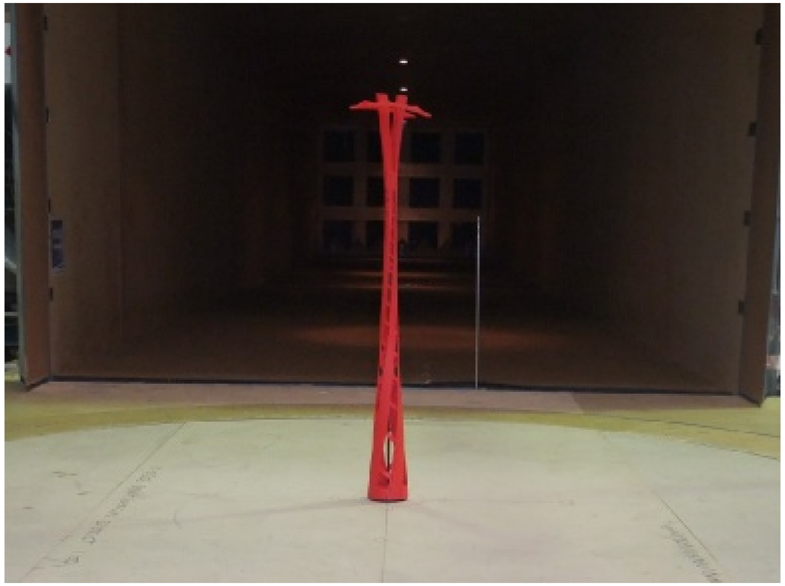


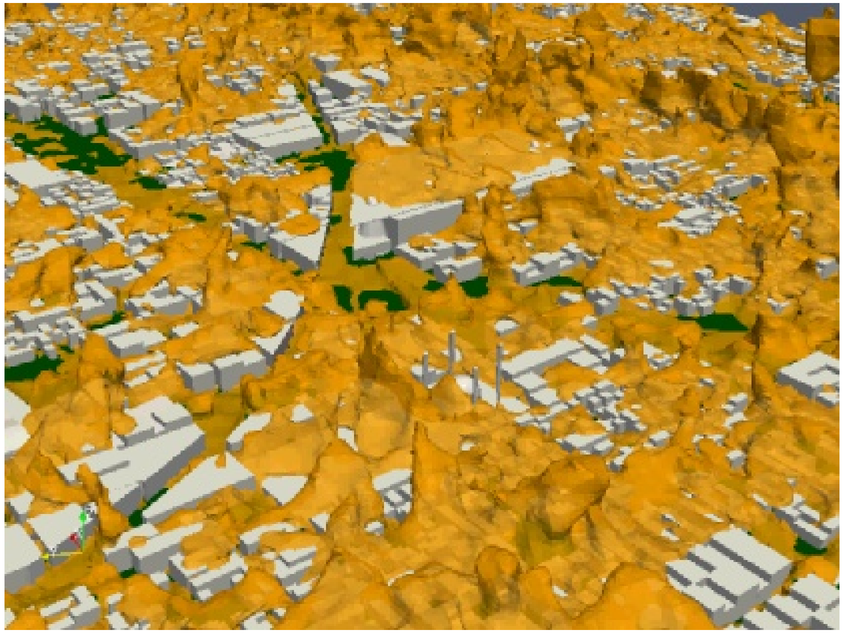
Don’t think of the wind as something that creates problems that need to be solved …



…consider all the issues at a concept stage and design to take advantage of the wind

Selected Projects

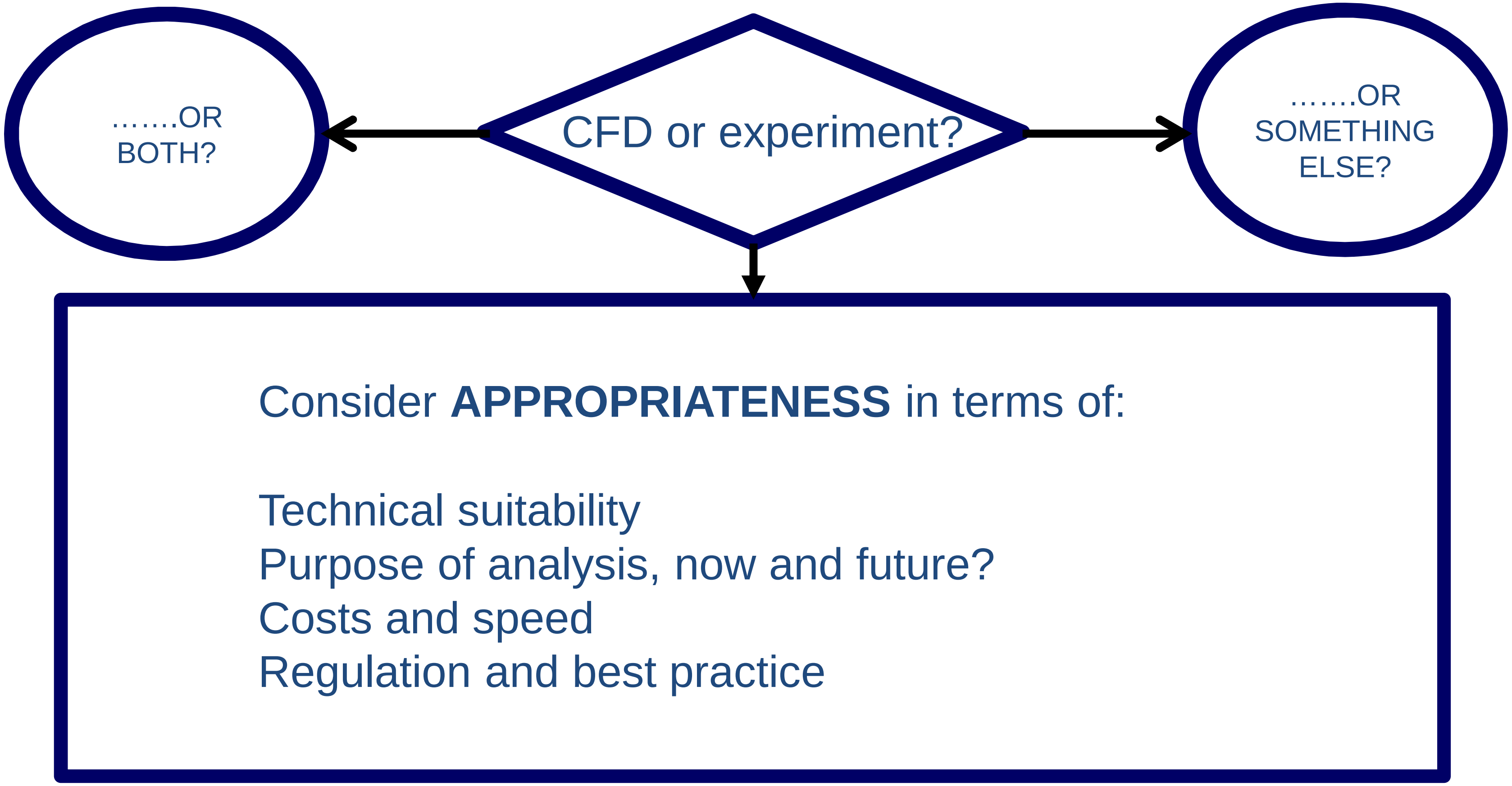




Wind Engineering

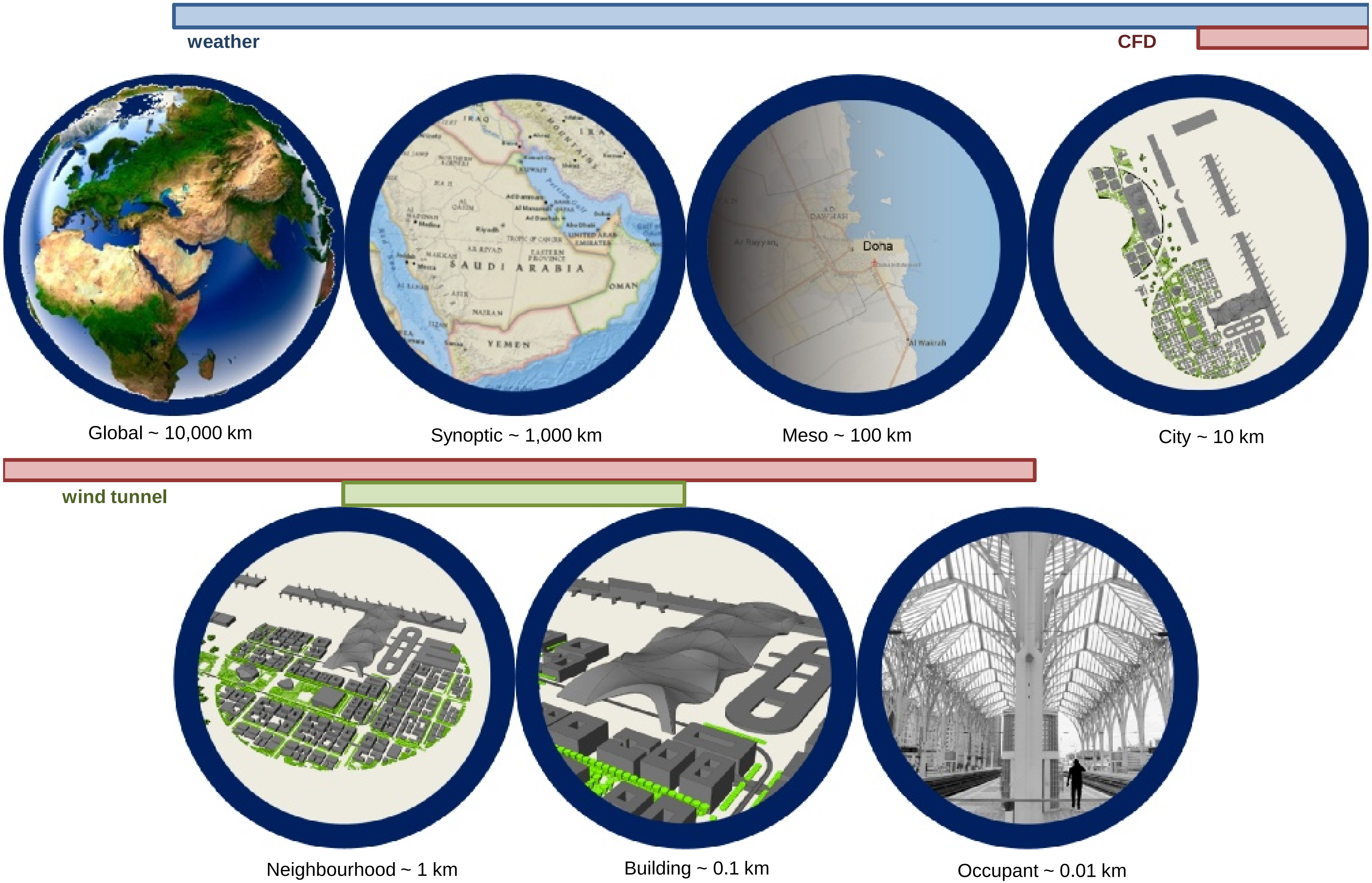
Comparison of CFD and Experimental Methods

CFD or Experiment in Wind Engineering?



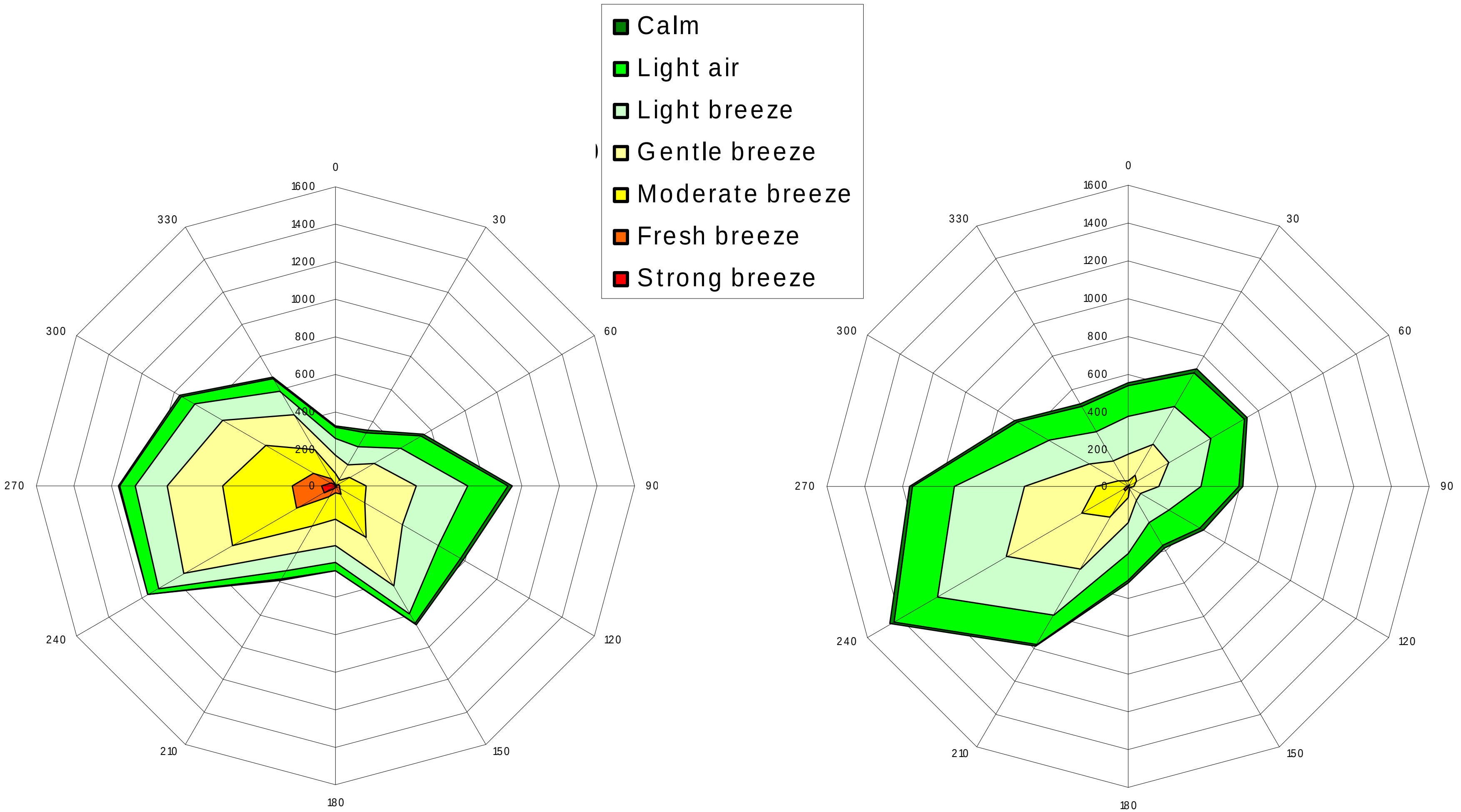
We use both approaches, but not for the same things!

Modelling Challenges : Scale



Modelling Challenges – Variability of Wind

Wind Roses – Regional Variation



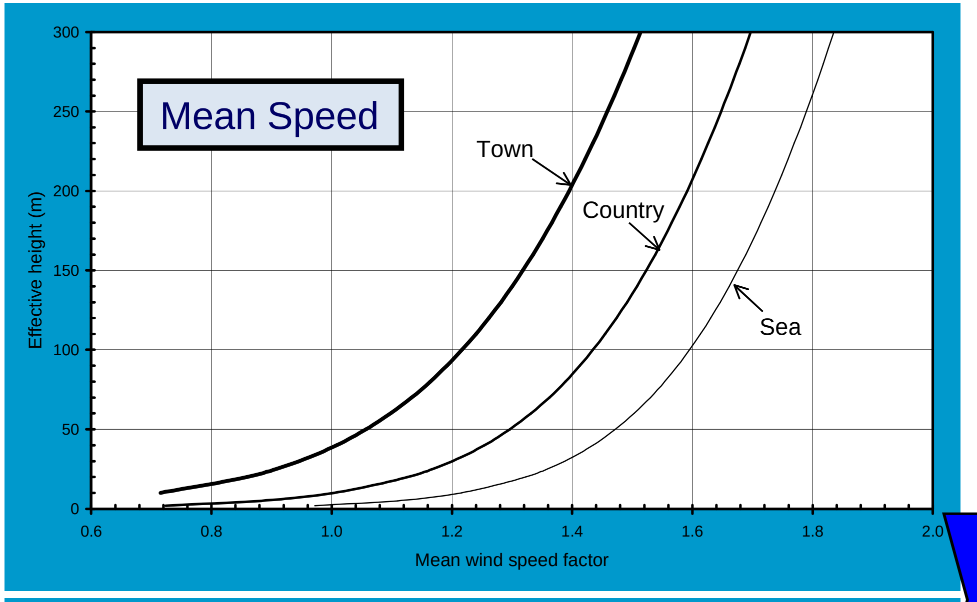
Squires Gate

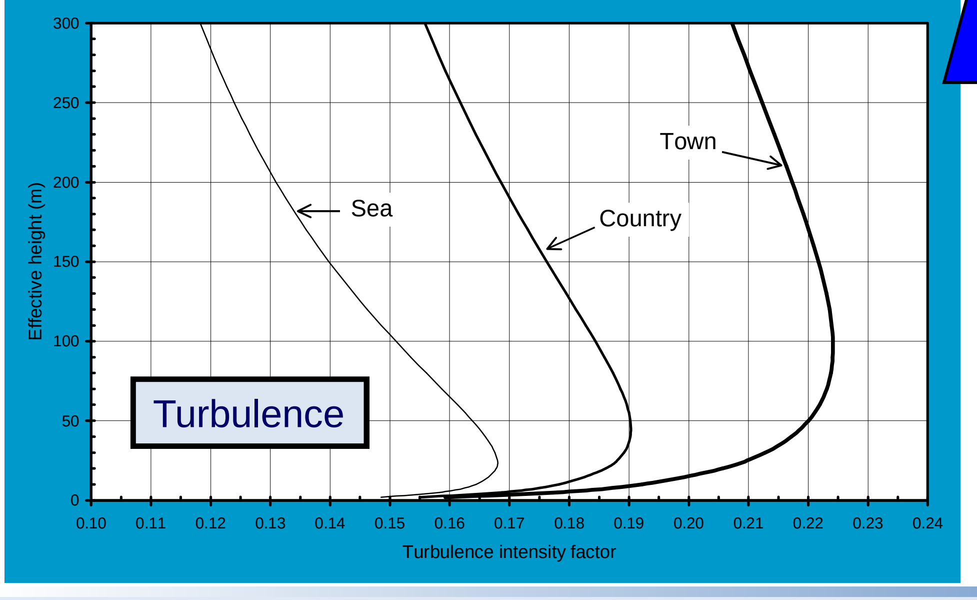
London

Annual variability requires modelling full 360° wind environment

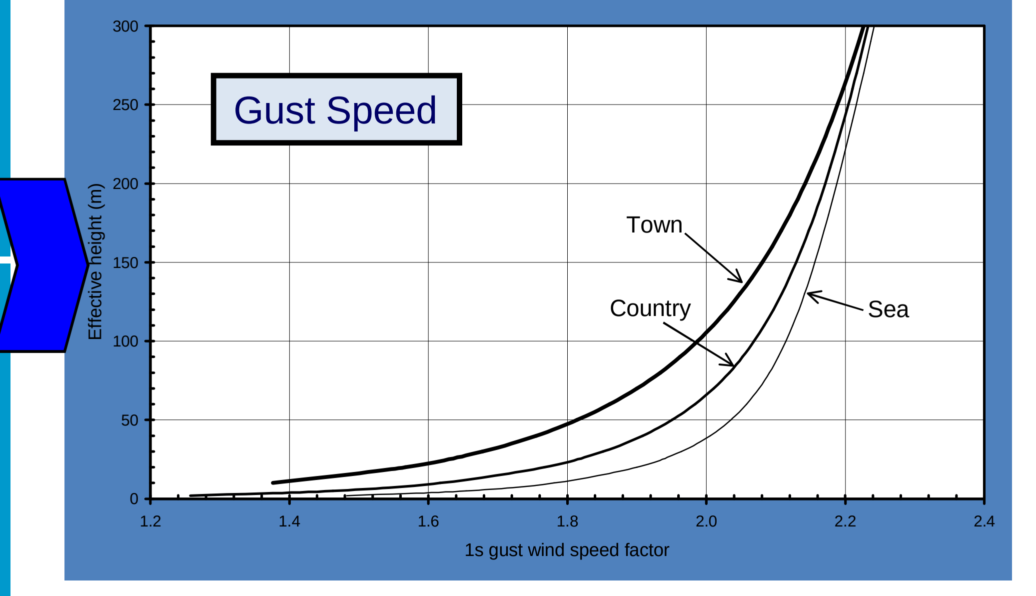
Substantial overhead in CFD

Synoptic winds – height profiles



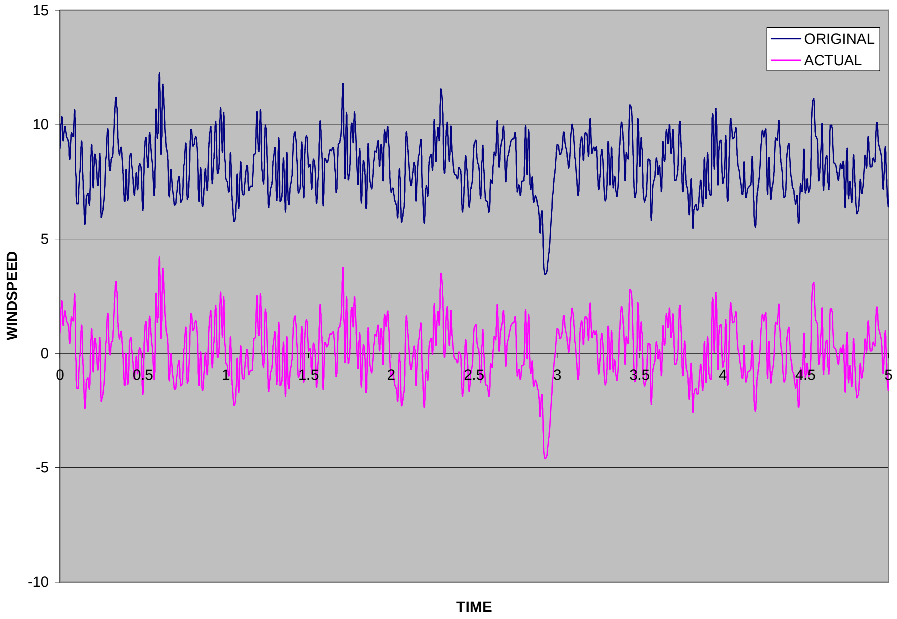


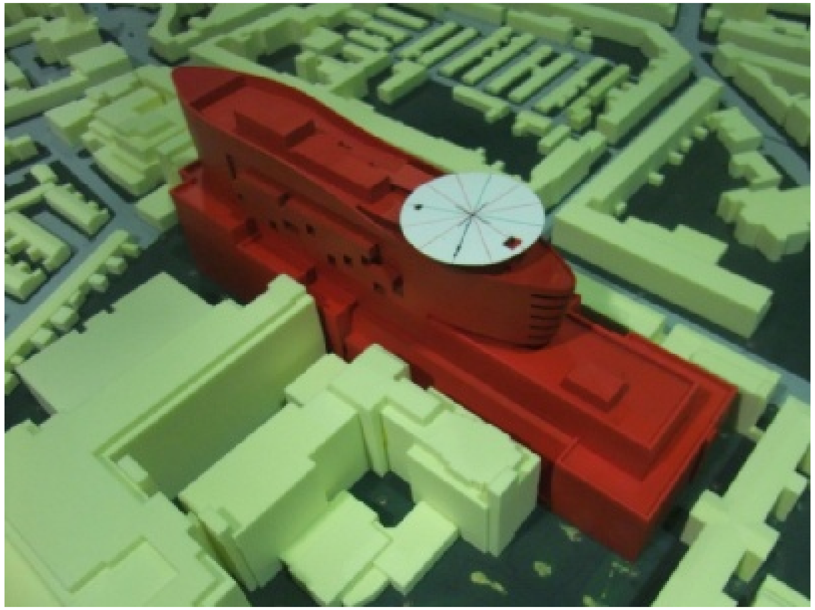
Shear
Turbulence
Terrain Roughness



Modelling Challenges – Depiction of Wind

Gustiness





Variability better represented in wind tunnel

Critical example: Helipad studies

Accuracy

Wind Tunnel	CFD
An analogue computer	On a digital computer
Unlimited resolution mesh is automatically generated	Mesh resolution limited and requires generation process
Full turbulence modelling	Simplified turbulence modelling
Short run times to converge	Convergence times can be long

Required accuracy will depend on purpose of analysis….

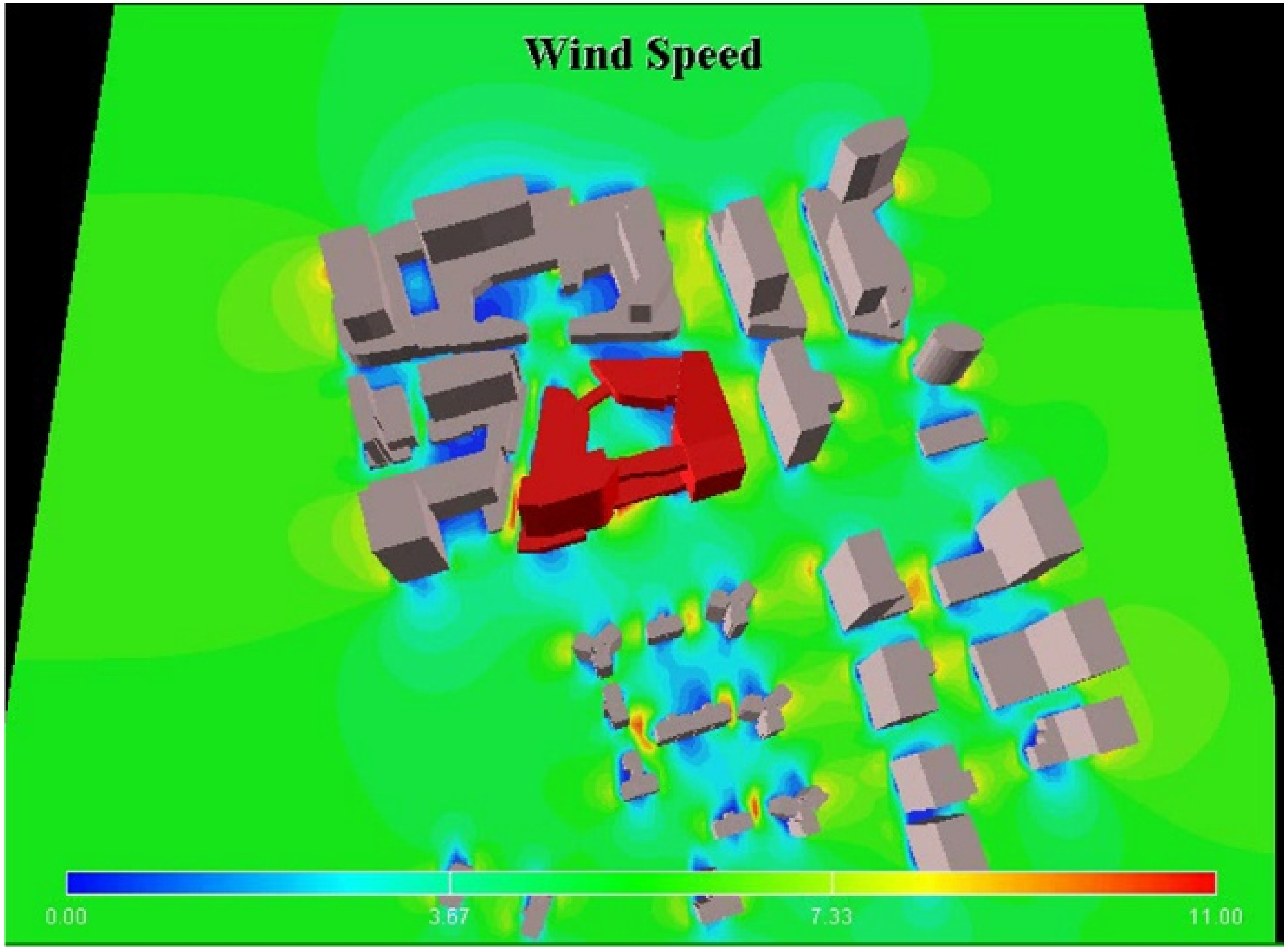
Spurious statistics:

Config x θ x locations x Sample = ca. 450,000,000 data points / study

Purpose of Analysis

Scoping Analysis / Parametric Studies

CFD easily altered, can be run quickly to evaluate directions of concern

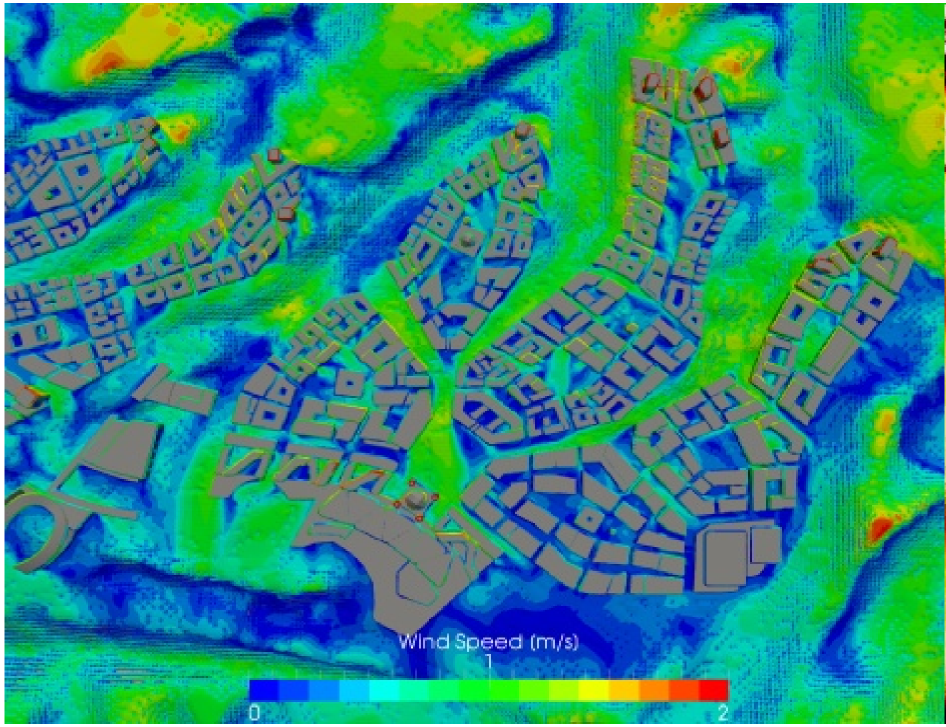


Purpose of Analysis

CFD convenient for combining wind and other climate modelling

Provides excellent visualisation for early stage parametric analysis

Example: Masterplanning



Purpose of Analysis

Detailed assessment for planning – best practice accuracy needed

Capturing and adjusting fine detail challenging in CFD

Examining statistical wind environment expensive in CFD

Fine Detail

Balconies and Landscaping

Wind Mitigation Measures

Costs and Time

Wind Tunnel	CFD
Model more costly	Lower cost for model
Short and low-cost running times	Longer, more costly running times
Phasing or “Fine tuning” model adaptations quick to run	Adaptations slow - require re-meshing/running
Full 360° wind environment at 10° resolution quickly	Multiple directions increase cost very substantially

Wind tunnel experiments often thought of as costly

but

Costs reduced via modern data capture and processing techniques

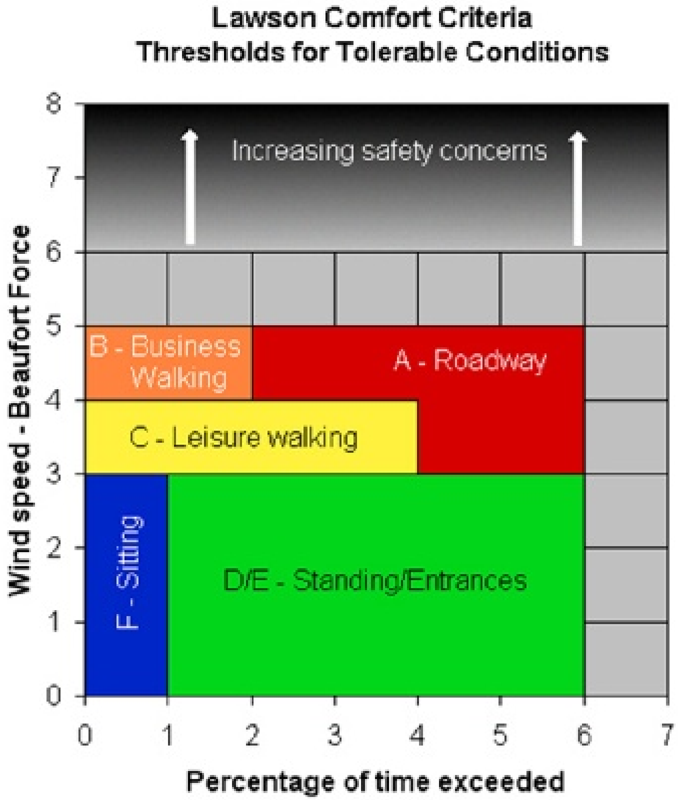
Cost often less than equivalent CFD for all but simple scoping runs

Regulation

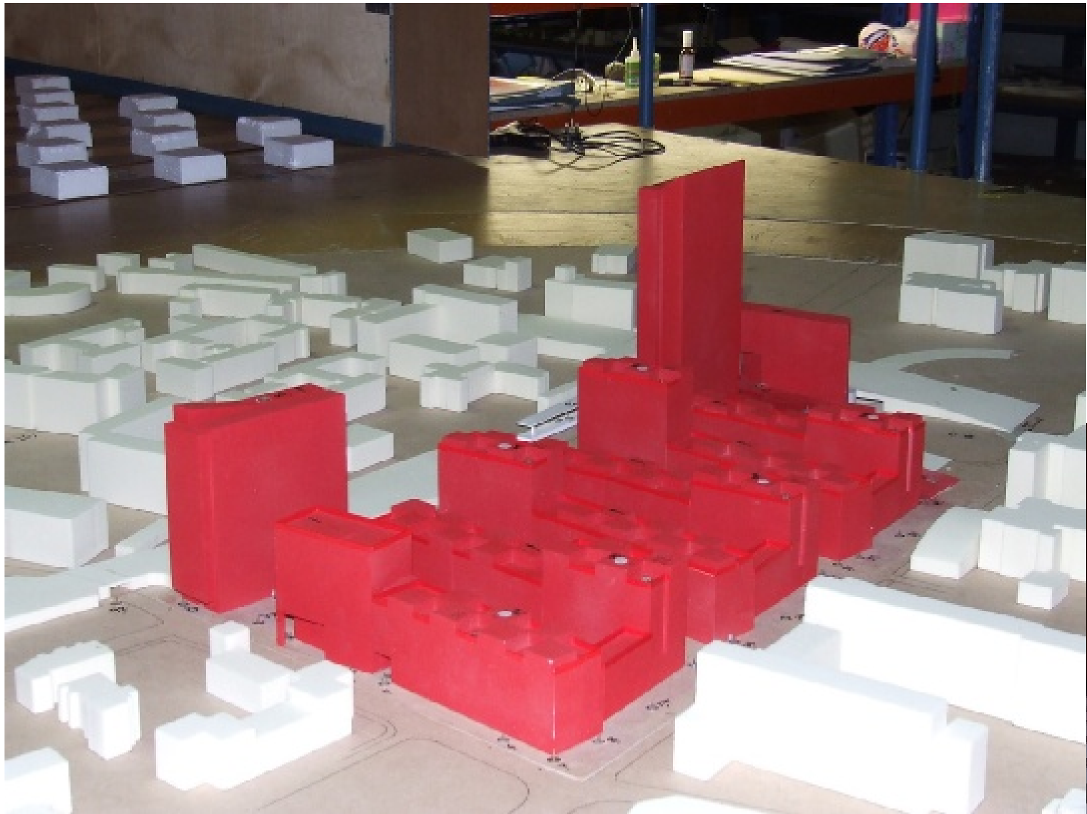
Generally, regulation not prescriptive in terms of methodology

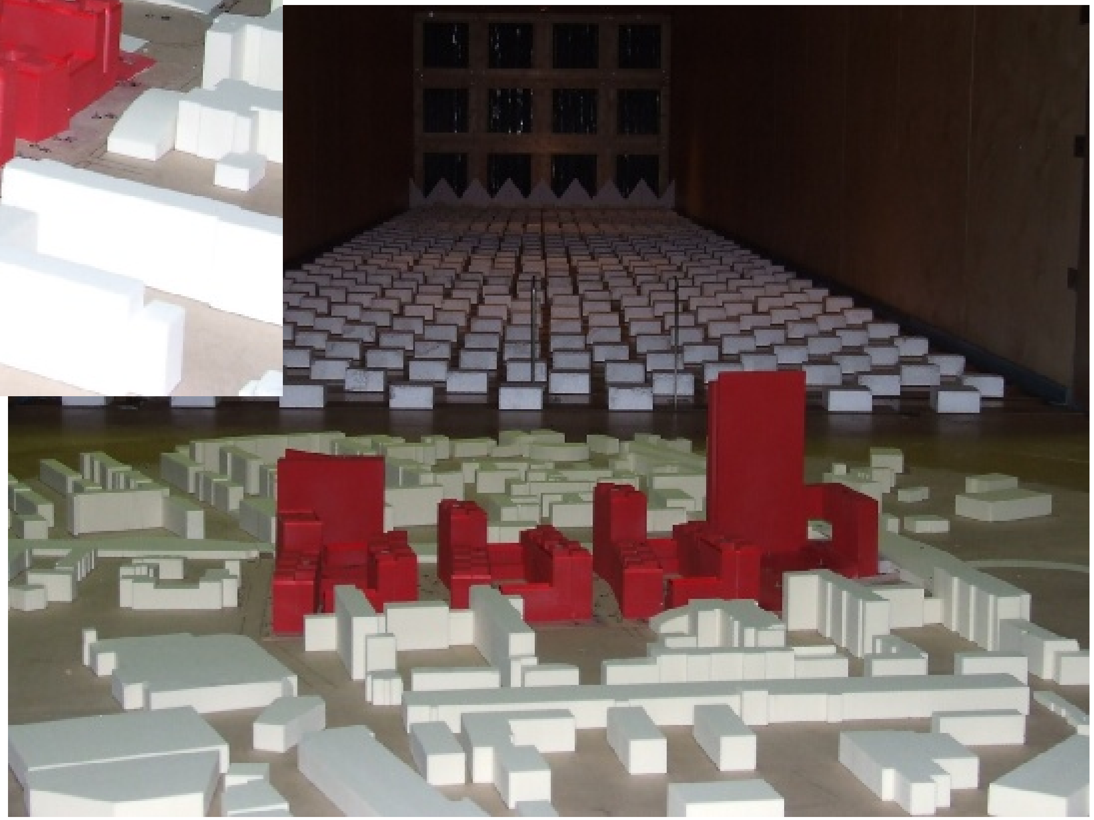
Advantages	Disadvantages
Promotes development of new techniques	Technologies may be misused

Detailed wind engineering regulatory requirements more easily proved by experiment than CFD (e.g. Lawson comfort criteria for pedestrian wind studies)



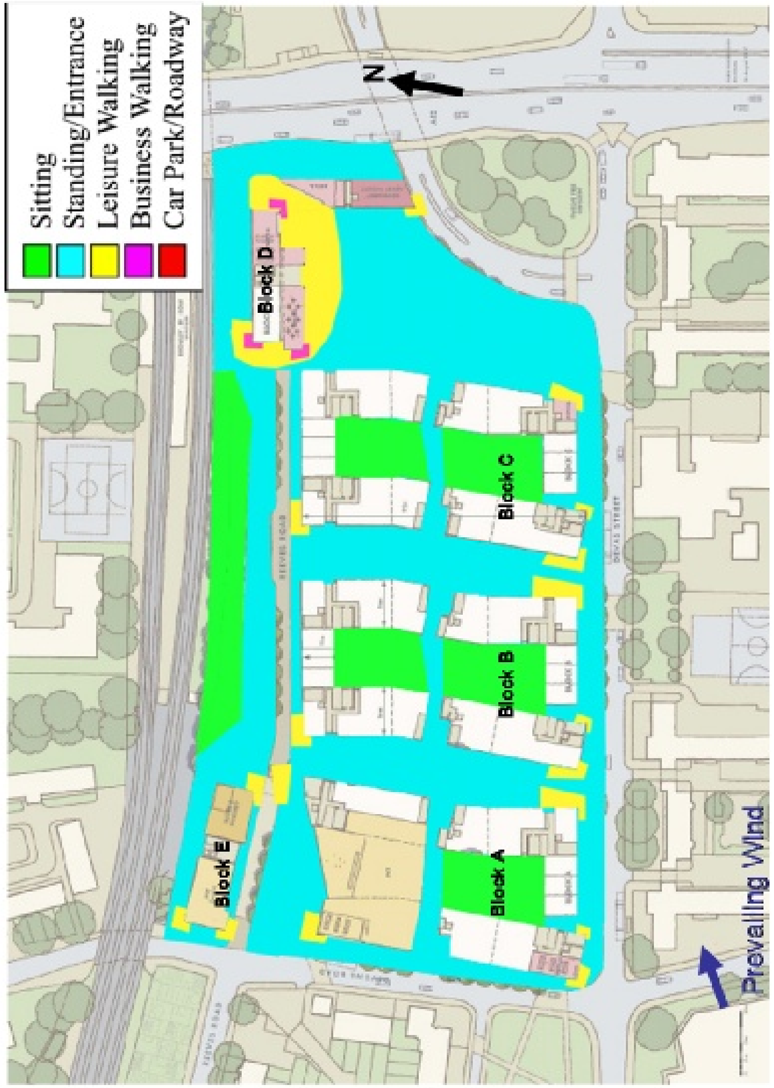
Other Approaches - Example

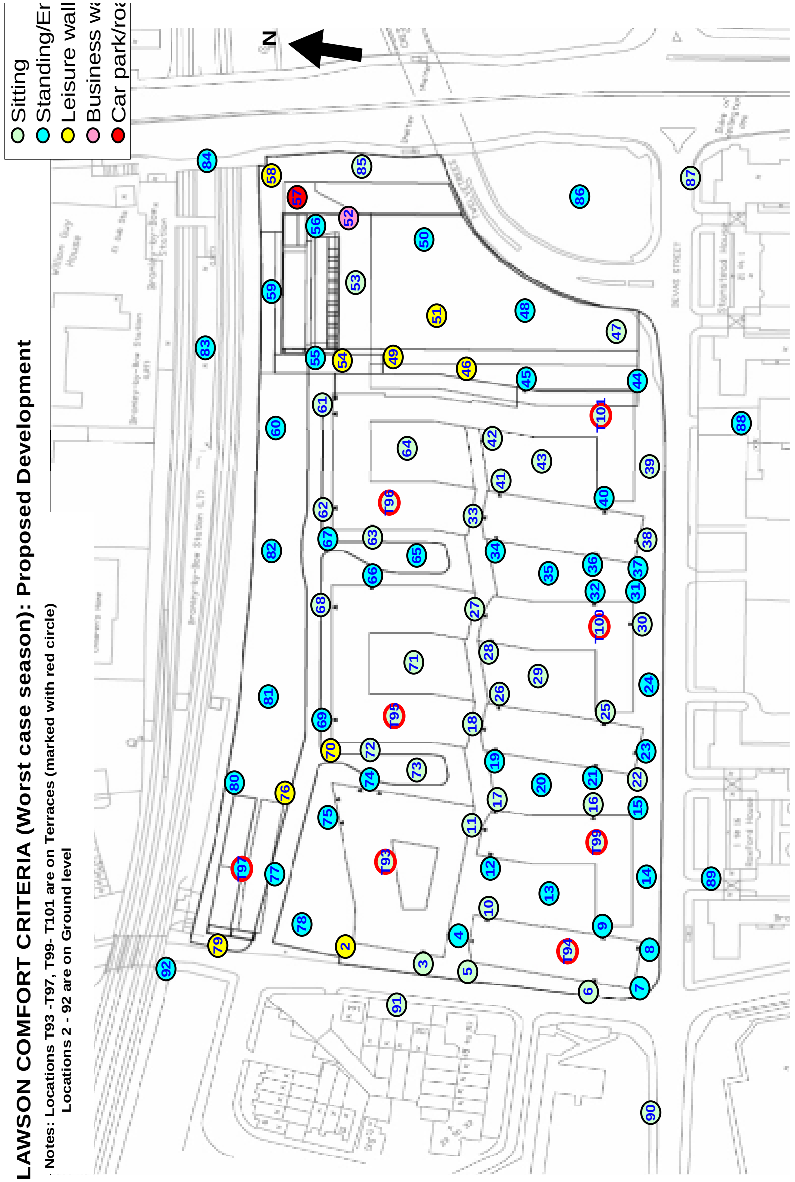




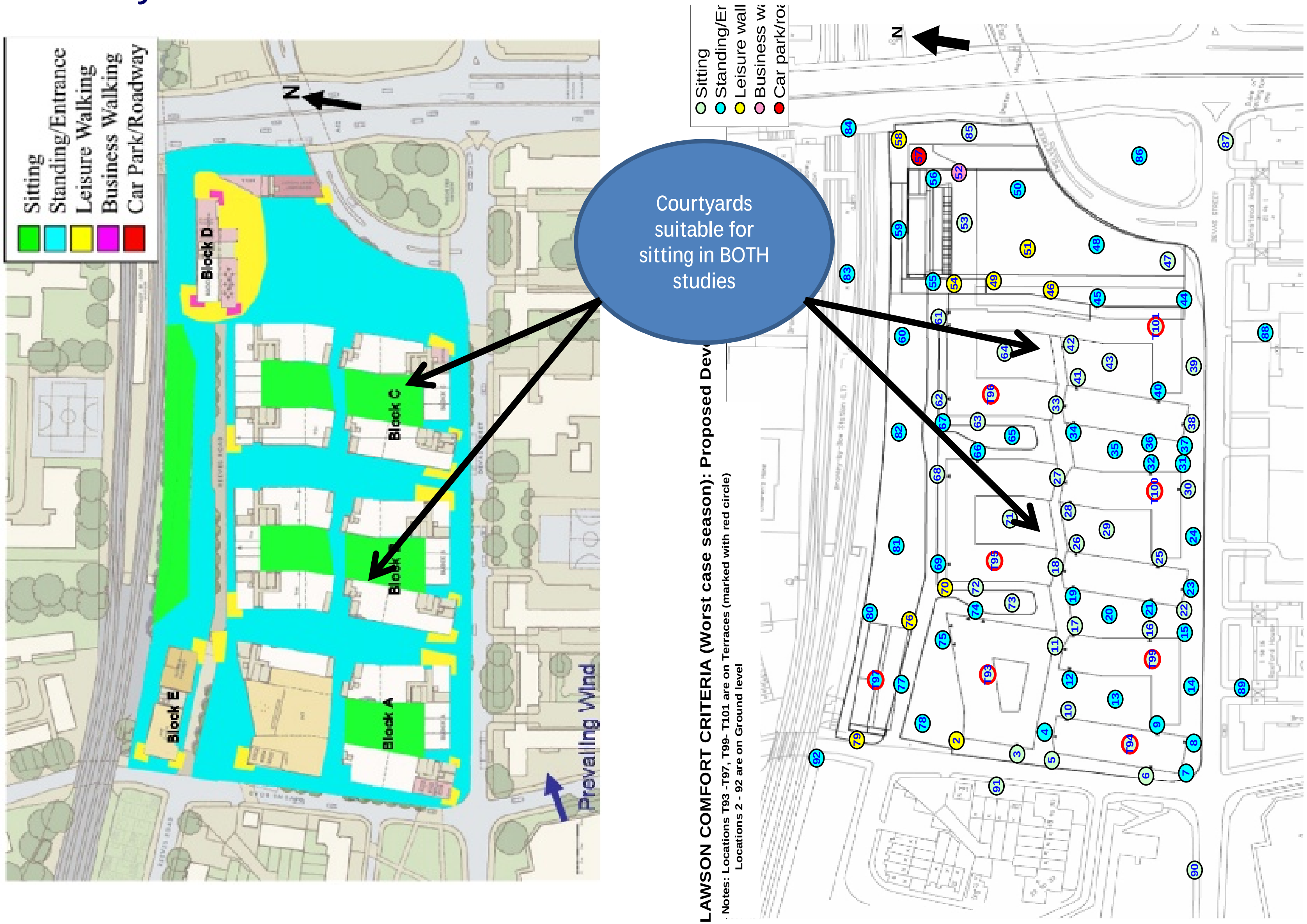
RWDI

Desk Study – Pedestrian Comfort

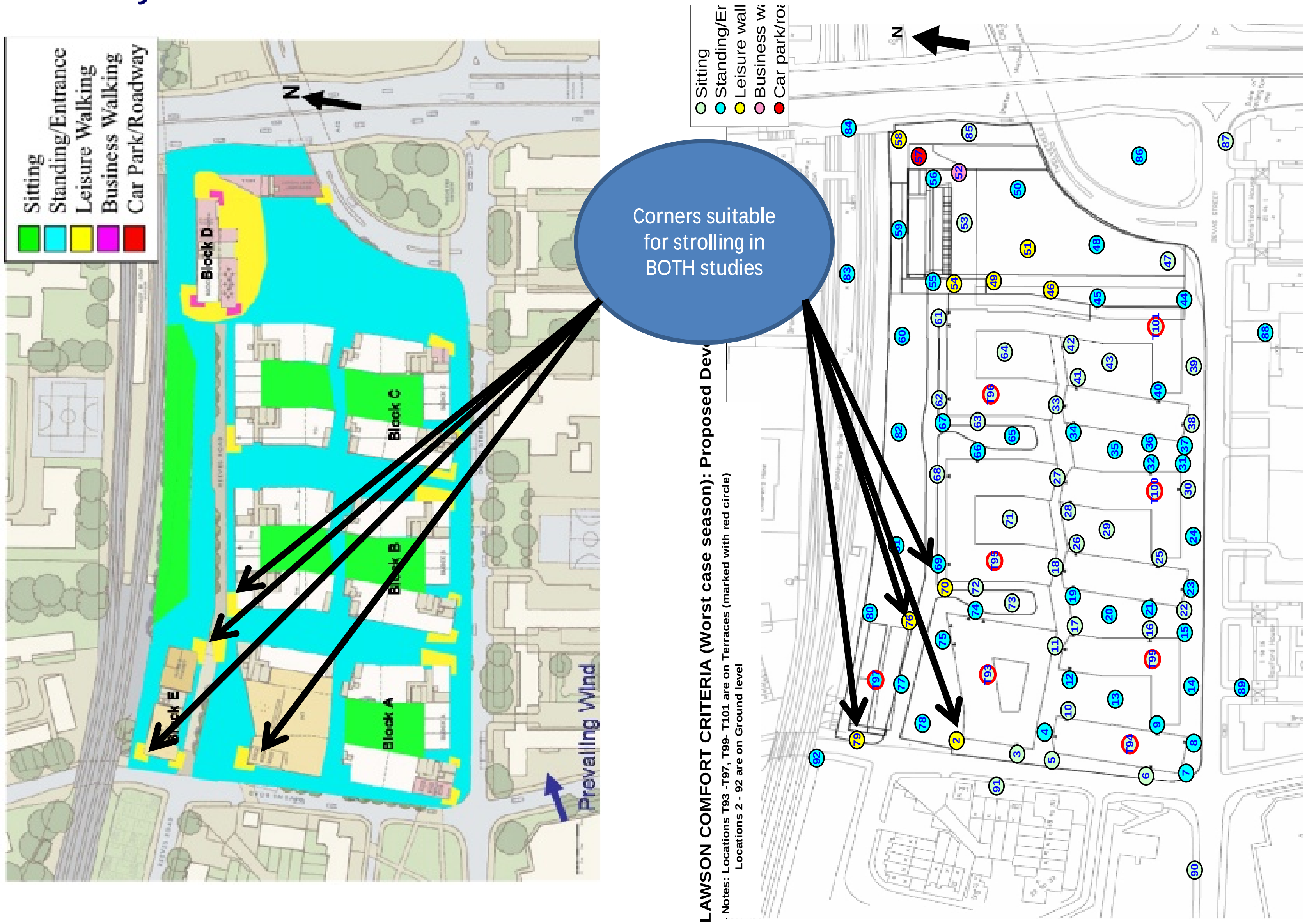




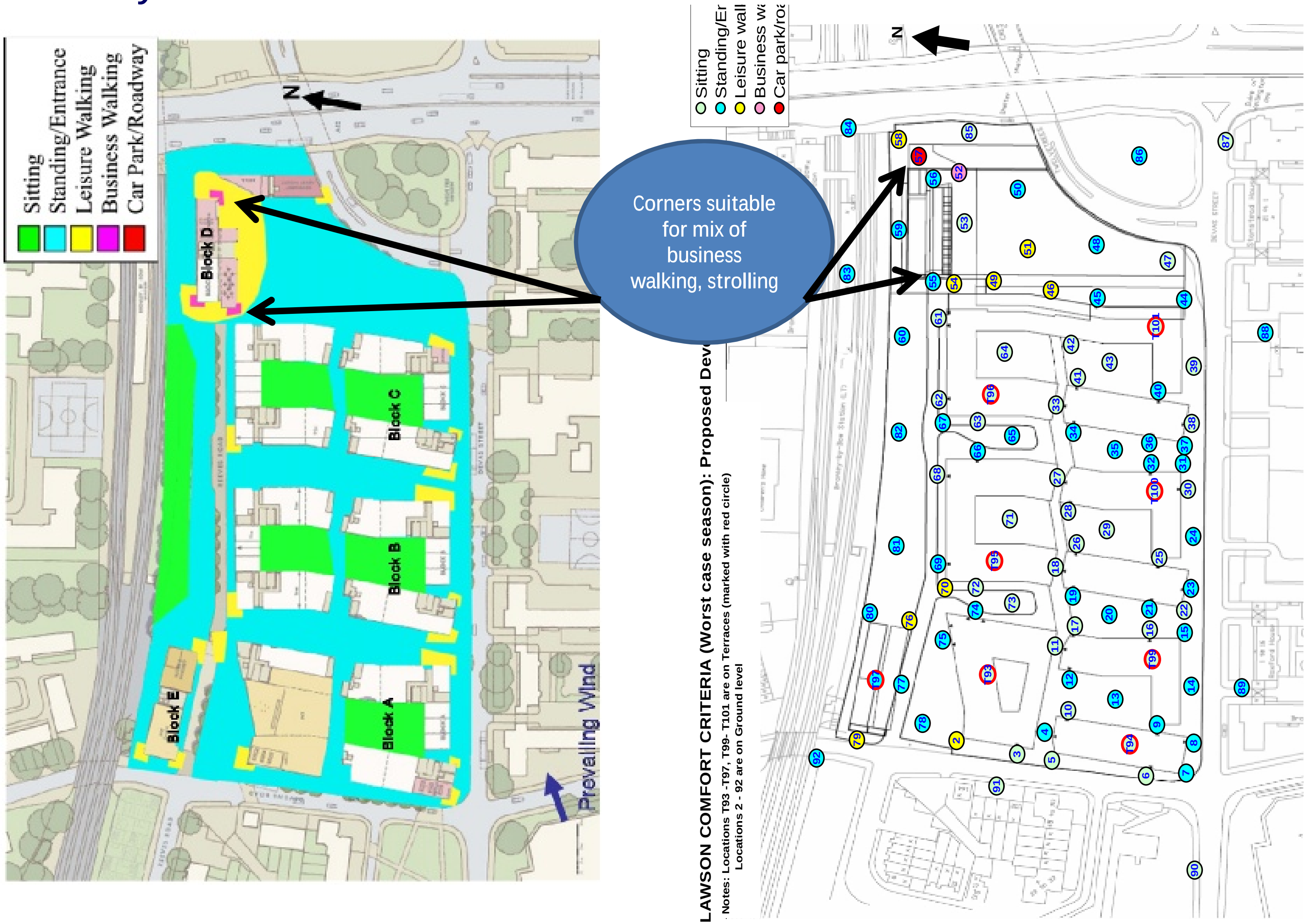
Desk Study – Pedestrian Comfort



Desk Study – Pedestrian Comfort

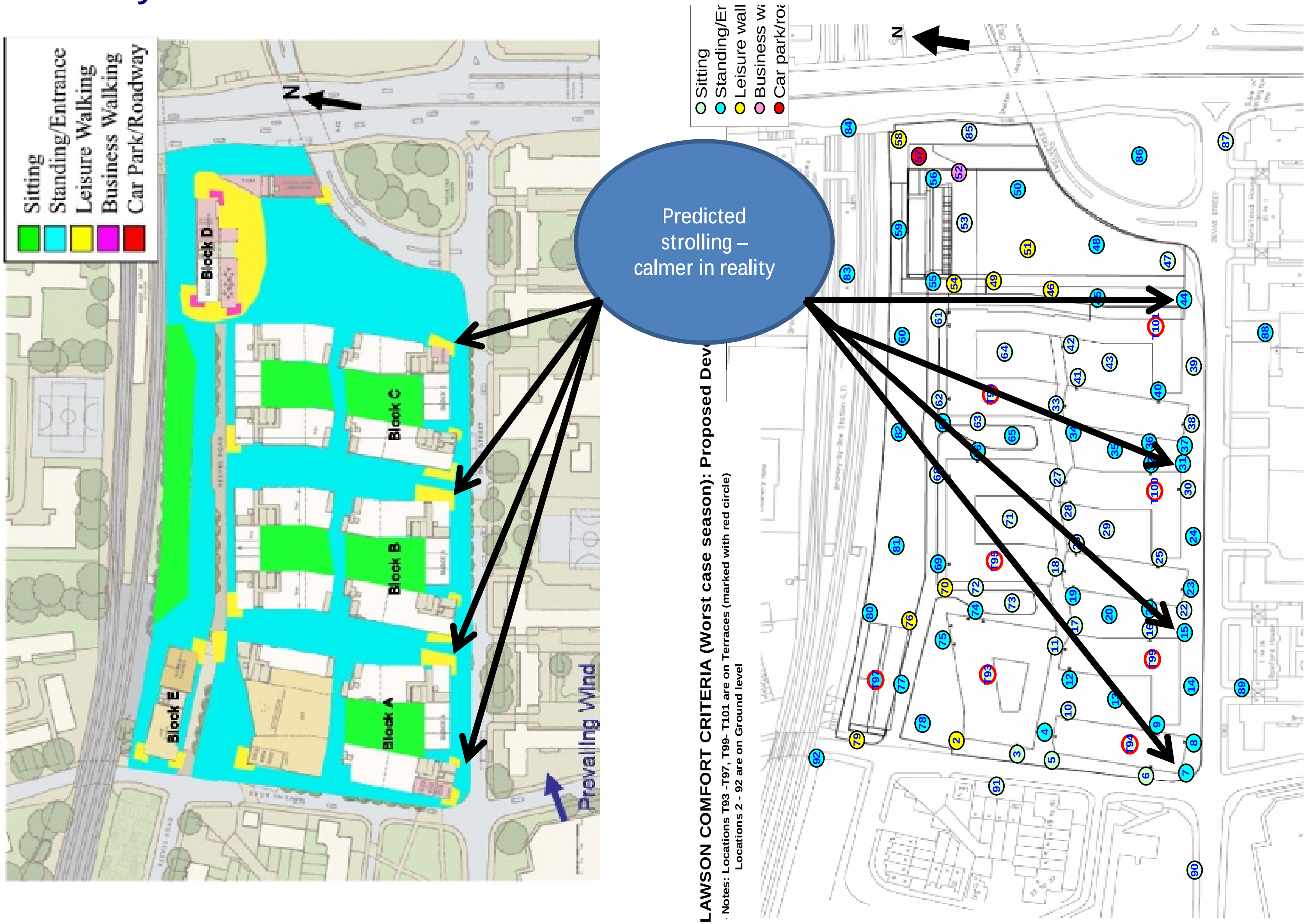


Desk Study – Pedestrian Comfort



Other Approaches - Example

Desk Study – Pedestrian Comfort



Case Study:

Using CFD to Examine Masterplan Microclimate

Masterplanning - Why Examine Urban Microclimate?

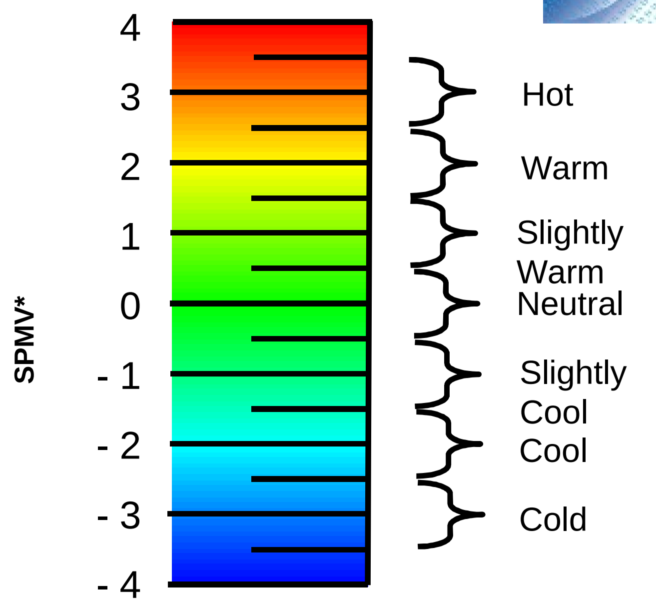
How People Perceive Climate

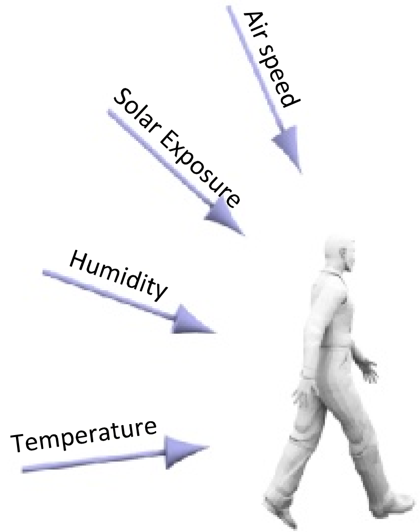
- Comfort is a complex phenomena
- It varies from person to person

- A combination of four environment variables
  - Wind speed
  - Temperature
  - RH
  - Radiant temperatures (solar impact, hot surfaces)

- Plus personal factors
  - Clothing levels
  - Activity

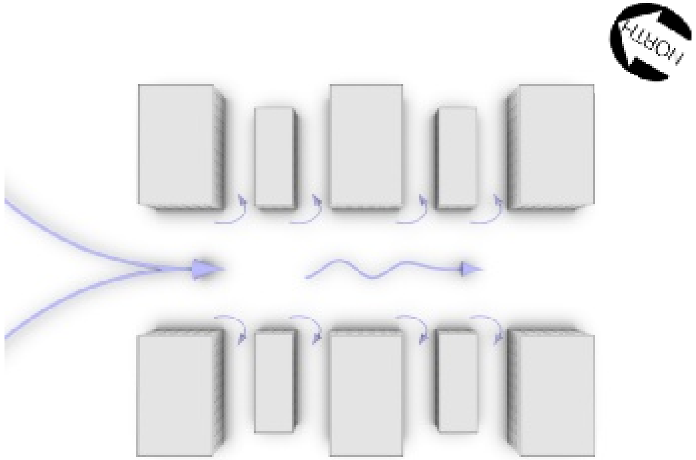
- Other parameters like gender, height have a lesser role.





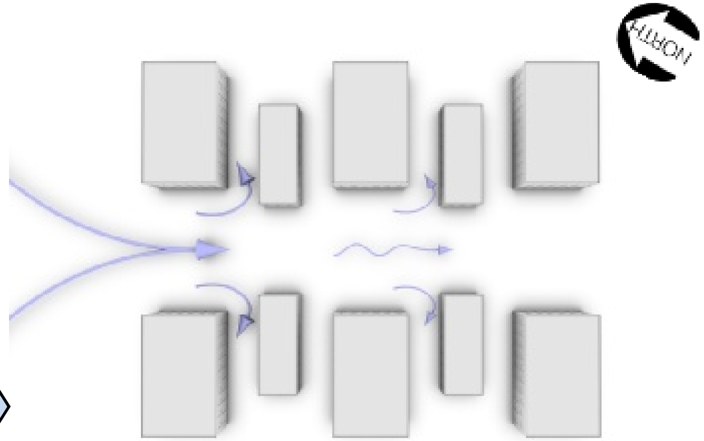
Masterplanning – How to Improve Comfort

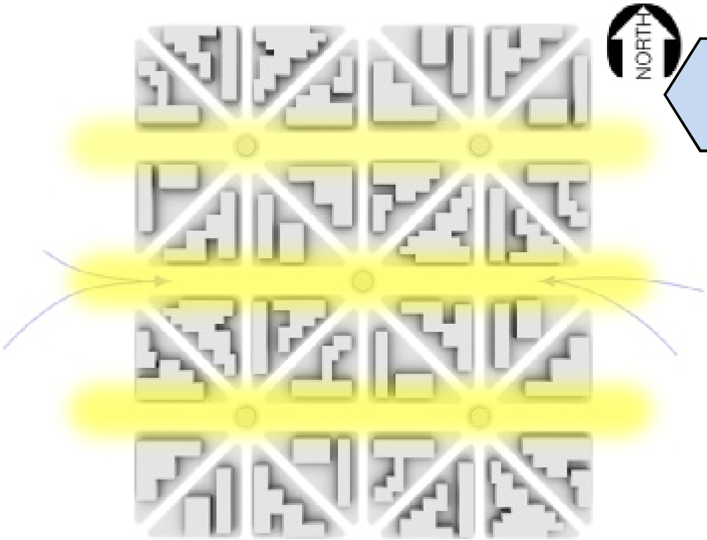
Layout & Orientation



Limited cross flow

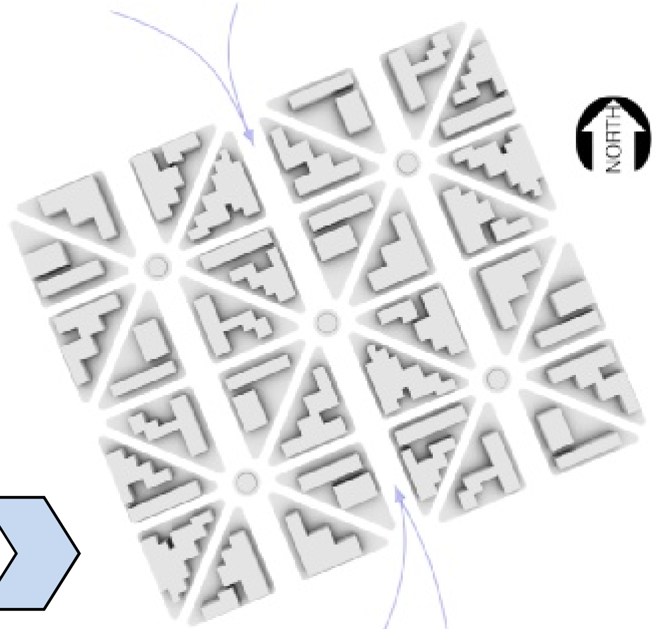
Broken lines encourage wind flow into side streets





East-West main streets are in direct sun all day during the summer months

This orientation allows maximum self-shading. Main streets encourage penetration of prevailing winds

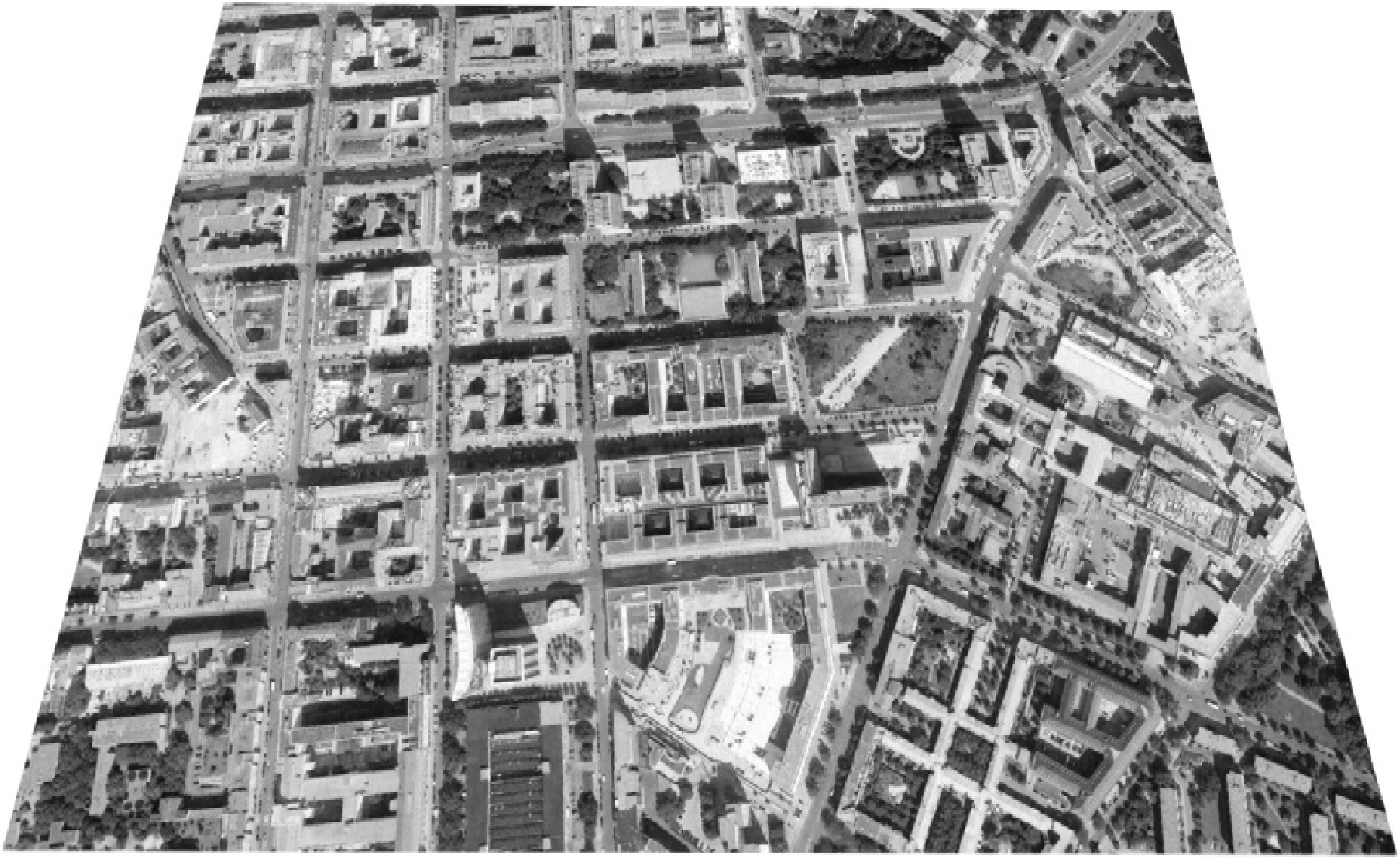


Typical Study Requirements - Masterplanning

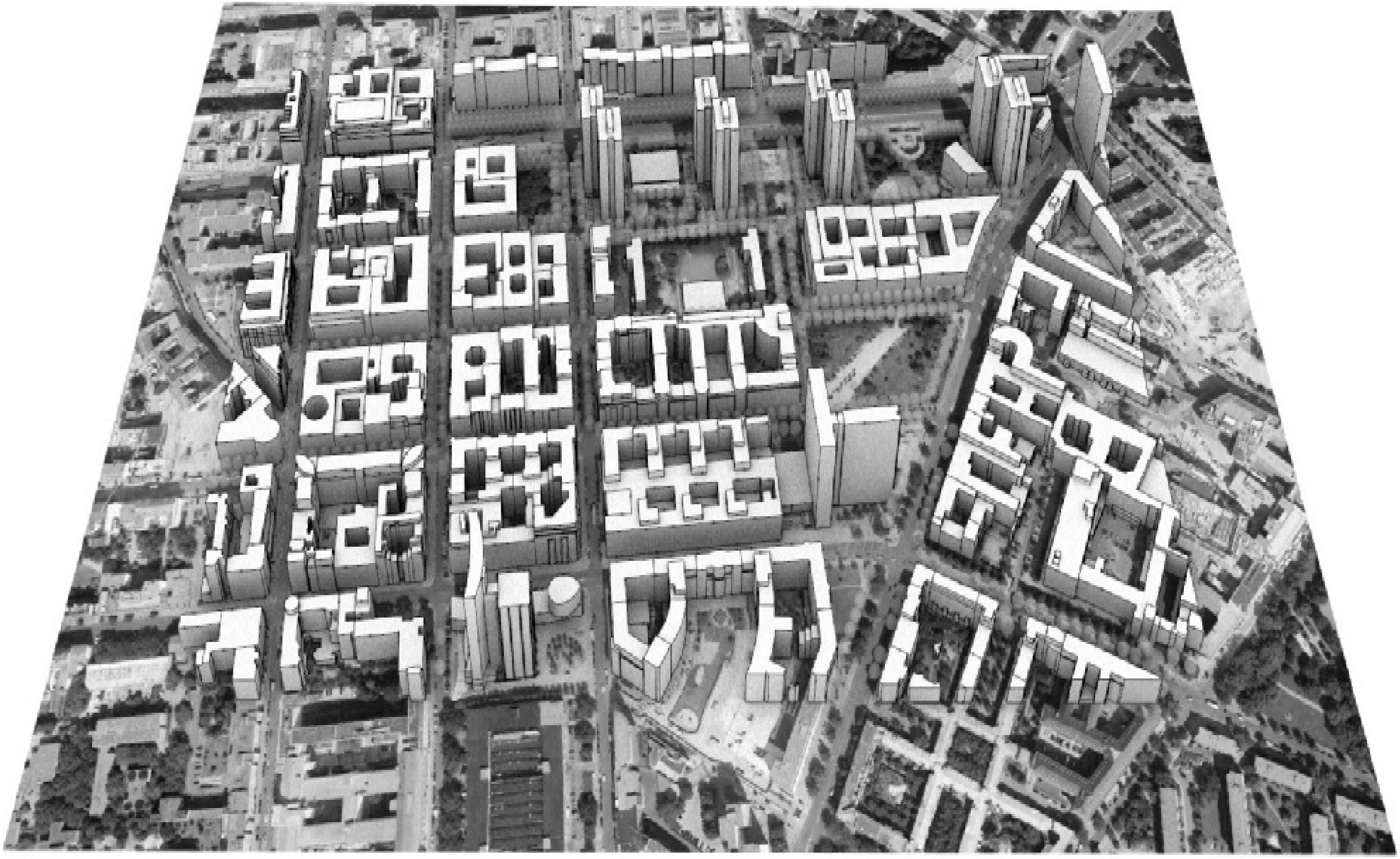
- Scoping level
- Identify main factors, make improvements
- Ease of visualisation important for client
- High-level decisions
- Not for regulatory purposes

Desk-based assessment or CFD appropriate

Berlin – Aerial Image of Site

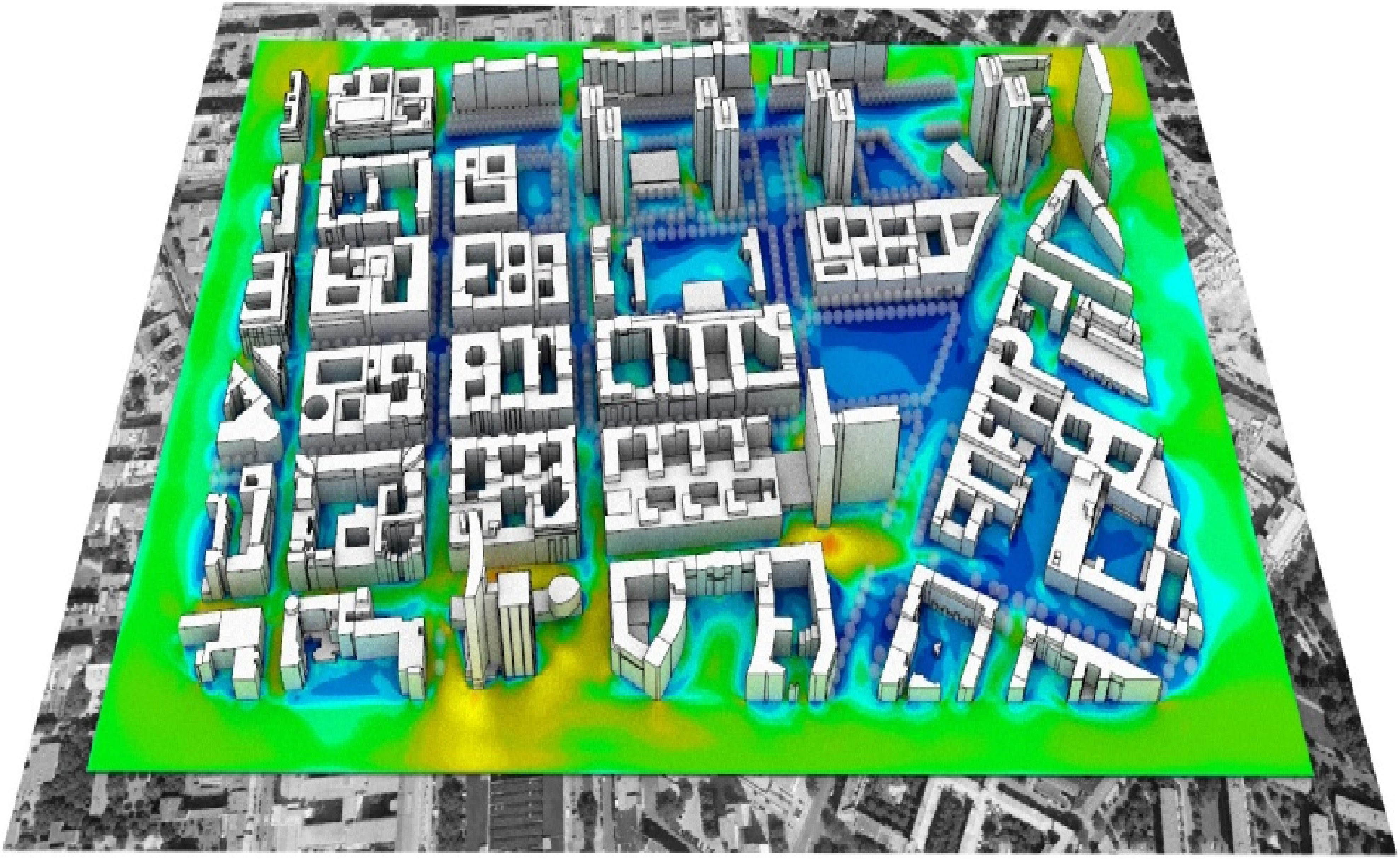


Berlin – Development

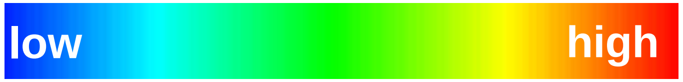


Modelling carried out combining CFD, solar modelling and statistical meteorological records

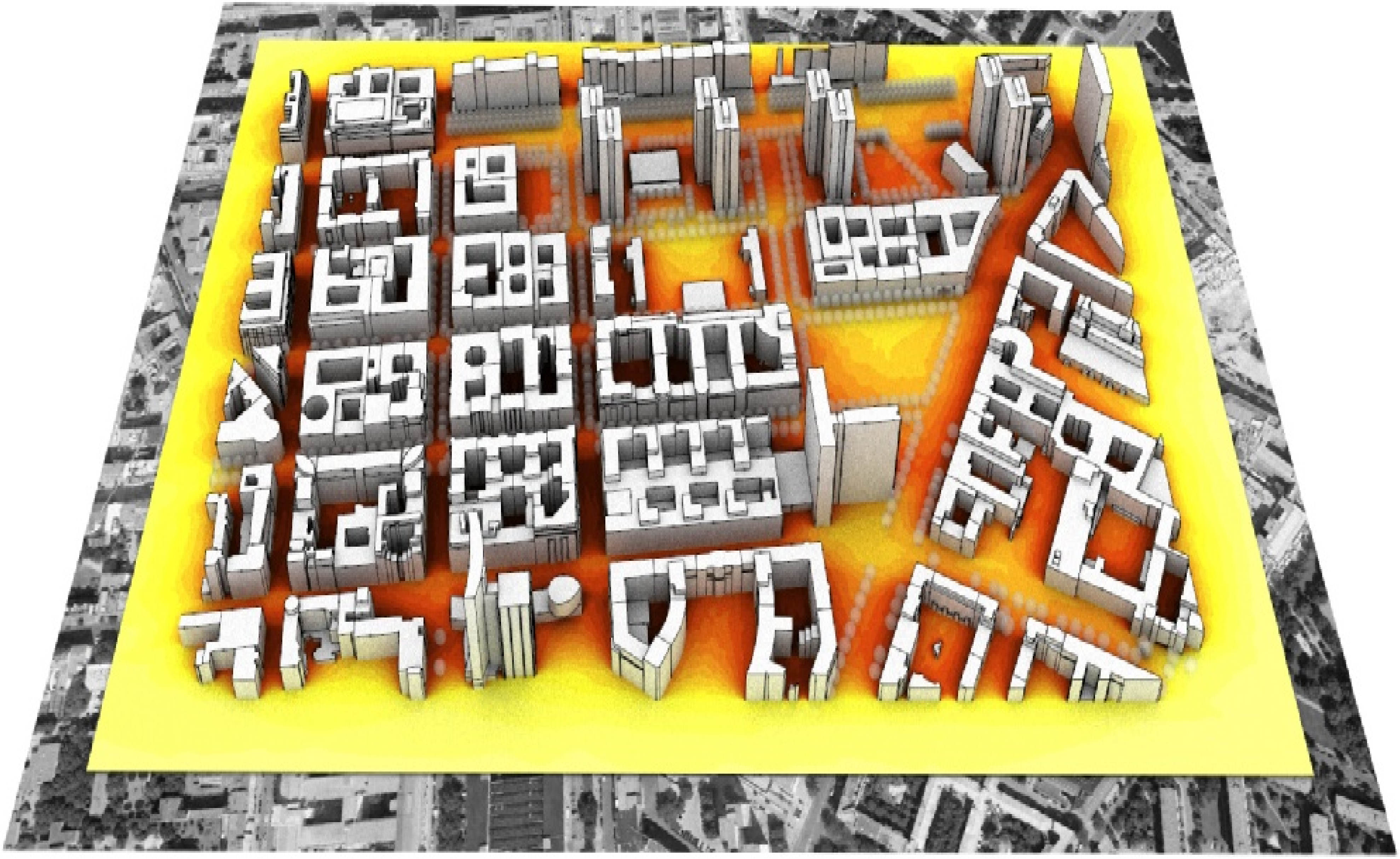
Berlin – Wind Speed



Annual mean wind speed (all directions)

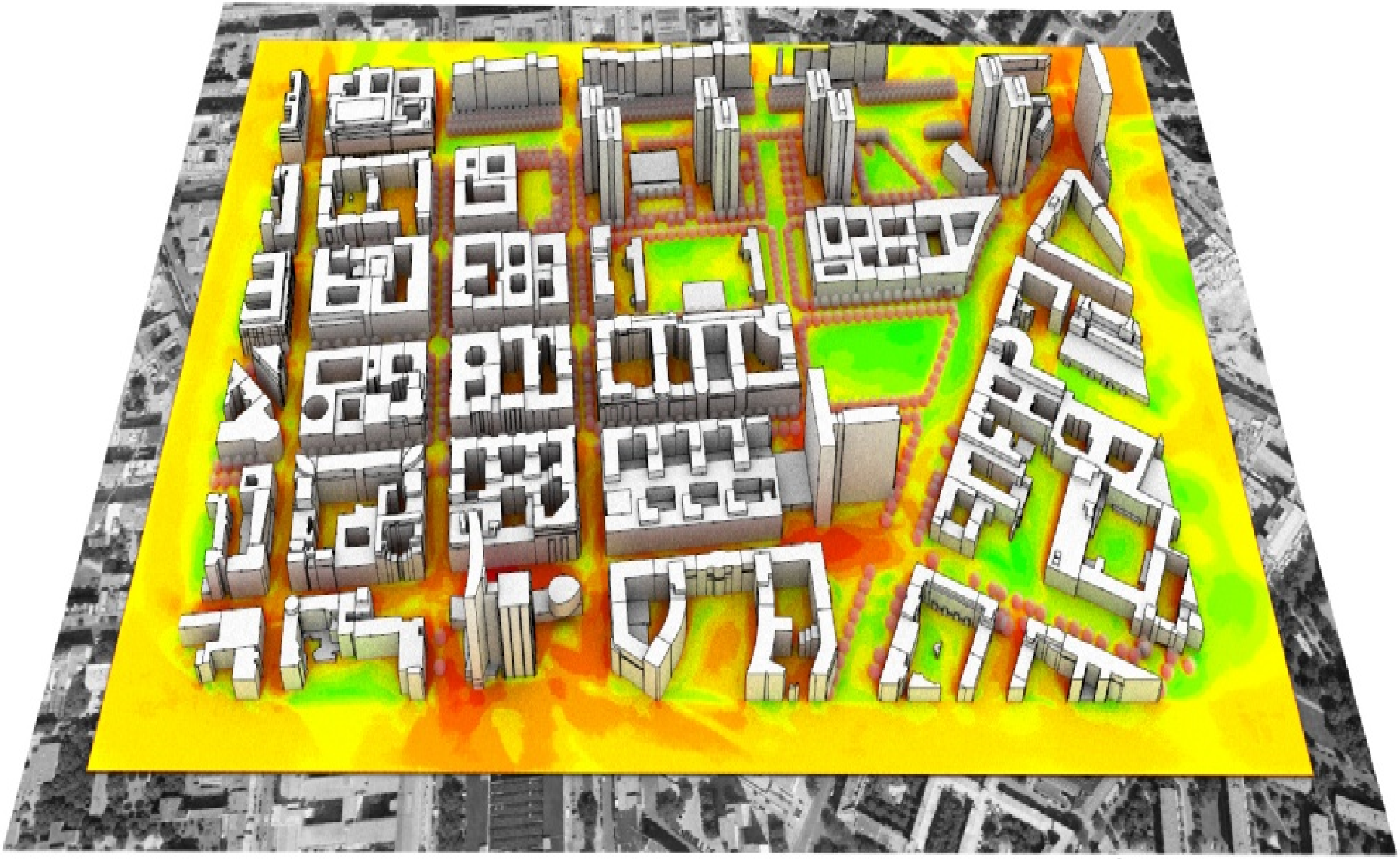


Berlin – Solar Exposure



Sky view factors – annual average

Berlin – Thermal Comfort

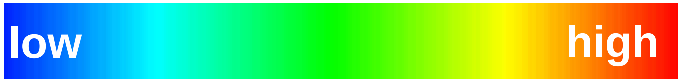


SPMV*

Berlin – Wind Chill

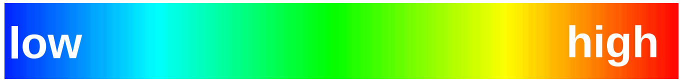
Berlin – Wind Energy Potential

Wind energy potential



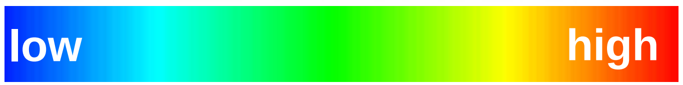
Berlin – Annual Solar

Solar radiation to surfaces (e.g. MWh/m²/yr)



Berlin – Façade Illuminance

Annual availability of daylight on facades

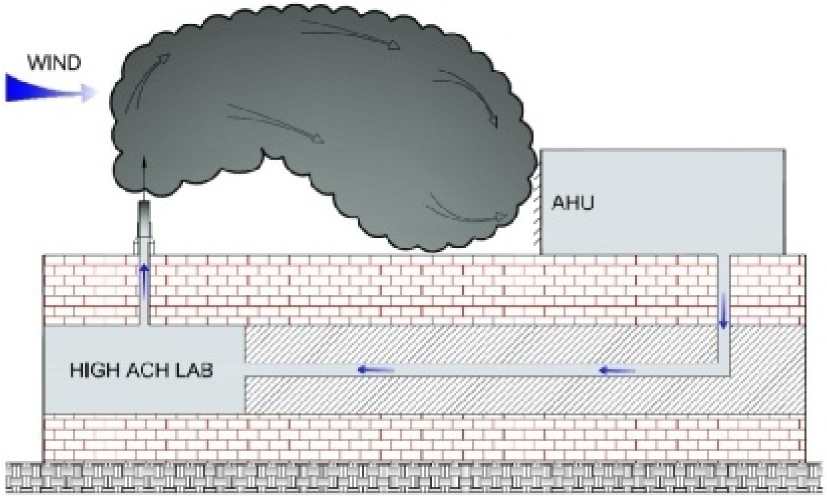


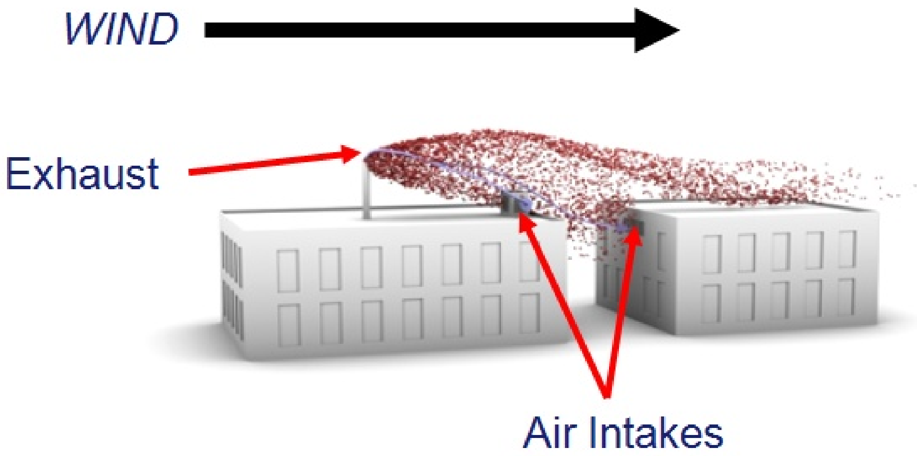
Case Study:

Exhaust Re-Entrainment

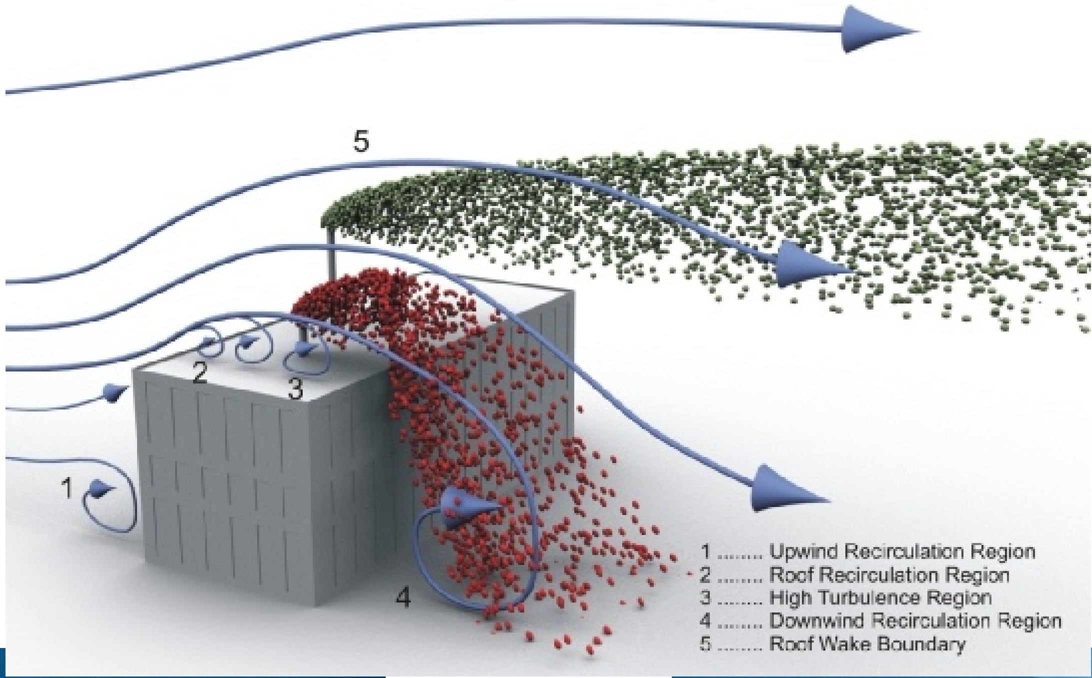
What is "Exhaust Re-entrainment"?

- Entry or re-entry of exhaust gases into a building that can lead to indoor air quality problems
  - Building exhausts into own air intakes
  - Building exhausts into neighbouring air intakes
  - Neighbour's exhausts into our building air intakes





Exhaust Re-Entrainment



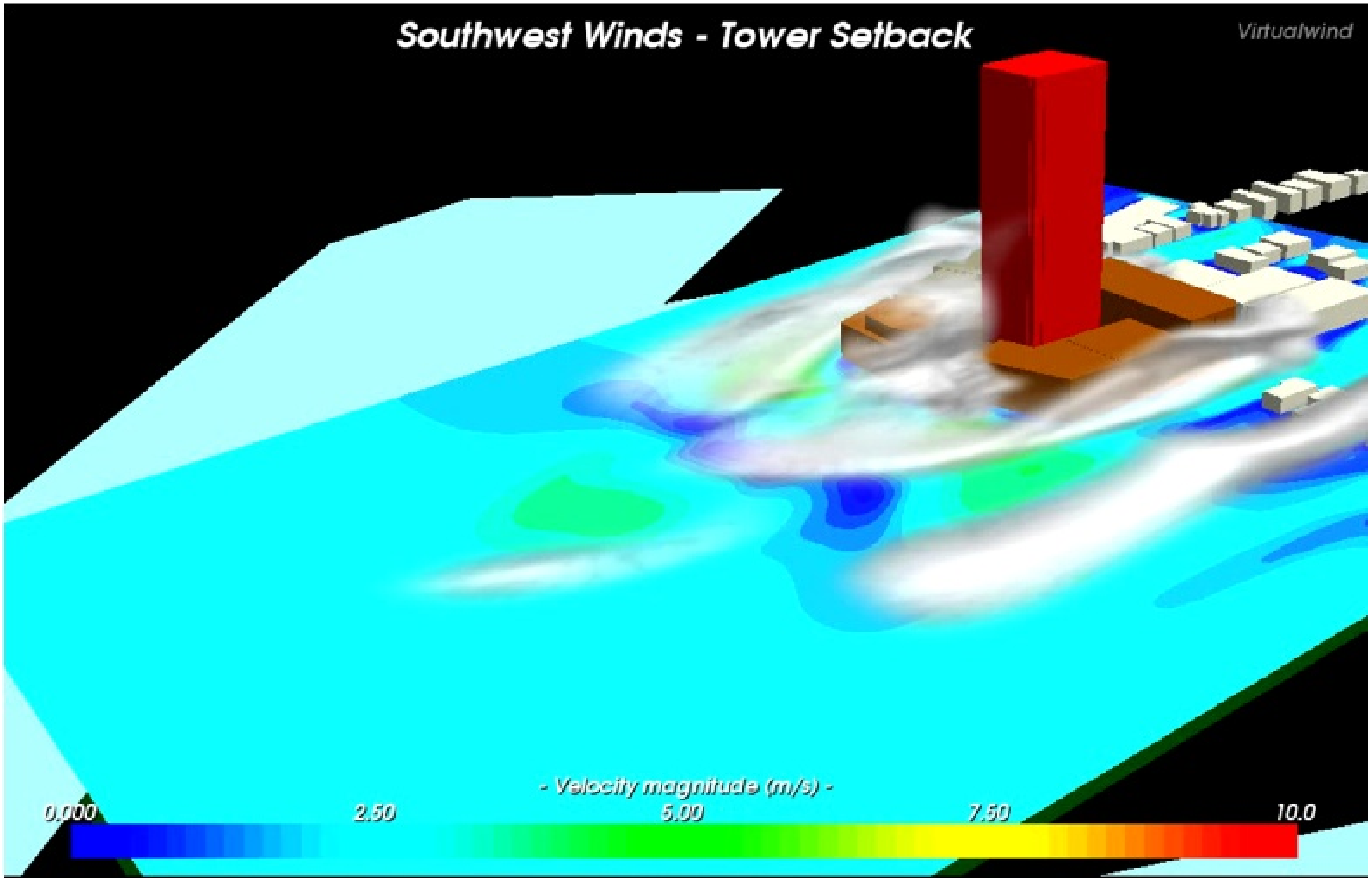
before raising stack height

after raising stack height

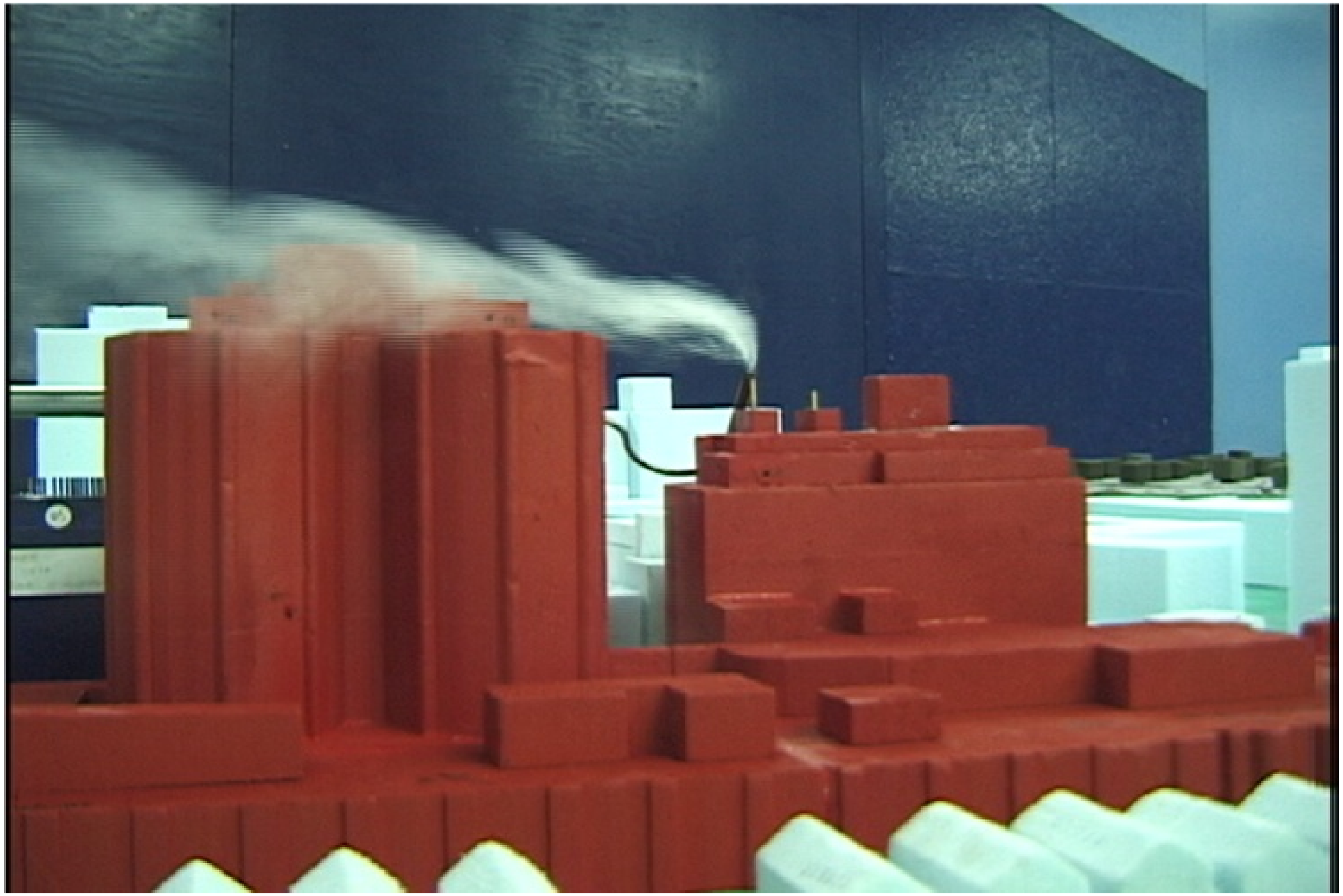
CFD Modelling: Exhaust Re-Entrainment

Computational Fluid Dynamics (CFD)

Quickly highlights potential issues

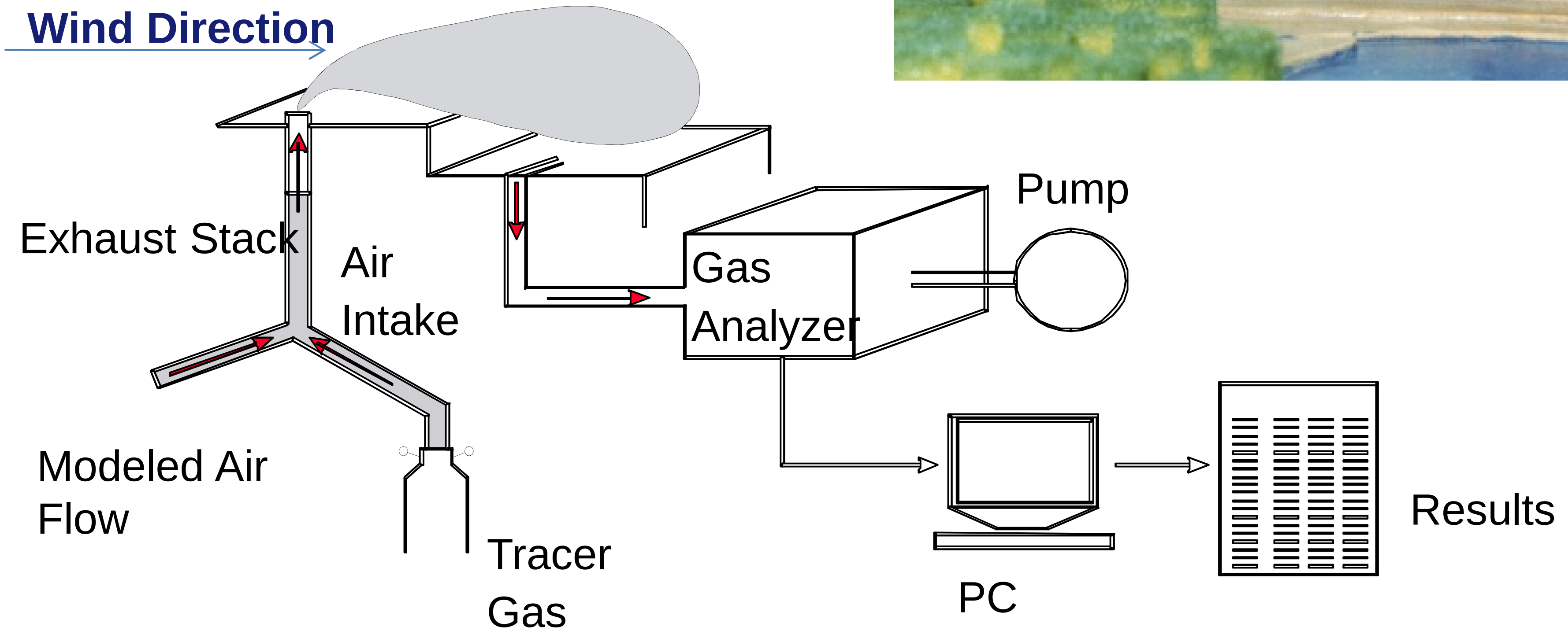


Example Results : Exhaust Re-Entrainment



Wind Tunnel Modeling : Exhaust Re-Entrainment

- Most accurate and reliable
- Accuracy important when dealing with gases with health impacts
- Fine-tuning designs
- Includes complex geometry



Typical Study Requirements – Exhaust Re-Entrainment

- Scoping level
- Identify if a problem is likely
- Few wind directions of concern
- Lower-impact problem
- Not for regulatory purposes

Desk study or CFD appropriate

- Detailed design
- Need to examine full wind environment
- Higher-impact problem
- Study to demonstrate regulatory compliance

Wind tunnel study appropriate

Conclusions

Conclusions

Choice of approach dependent on the purpose of the analysis

- CFD useful for scoping problems; less appropriate for final approval and fine detailing.

- Experimental methods fast to run once model is built; both mean and gust conditions are simulated; requires expert teams

- Pedestrian comfort and structural regulations generally don't favour specific methods but standards more easily met by wind tunnel experiments.

User should define purpose of the study, configurations to be assessed and required future flexibility before deciding on approach.

- Wind tunnel experiment costs biased towards creation of model, CFD spread between model creation and run time.

- Costs of experiments can be competitive with CFD (particularly when the unexpected happens!).

Thank you for your time and attention

Are there any questions ?