



Objectives

- To **inform** the audience of wind effects on the built environment, from very low wind speeds to very high wind speeds, paying particular attention to the issues of serviceability and resilience.
- To **illustrate** these effects with examples of work carried out by colleagues and co-workers at Birmingham and elsewhere.
- To **irritate** and provoke wind engineering colleagues by criticism of current practice and identification of new issues.

Definitions

- Serviceability** – the ability of a structure / network / engineered environment to function in most wind conditions
- Resilience** – the ability of a structure / network / engineered environment to function when impaired by severe wind conditions and to recover rapidly when such conditions have passed
- Failure** – the failure of a structure / network / engineered environment in severe wind conditions from which recovery is not possible.

Contents

- From low to high wind speeds
- Techniques
- Information, illustrations and irritations
 - Discomfort
 - Distress
 - Disruption
 - Damage
- Concluding remarks




Serviceability and Resilience


From low to high wind speeds

	Illustrations	Mean wind speeds		
Discomfort	Pollution dispersion Pedestrian comfort	< 7.5m/s	Low <10m/s	Serviceability
Distress	Pedestrians Cyclists	5 – 15m/s	↓	Serviceability / Resilience
Disruption	Treefall Roads networks	10 – 20m/s		Resilience
Damage	Small scale storm systems Flying debris	> 17.5m/s	High >20m/s	Resilience / Failure

From low to high wind speeds

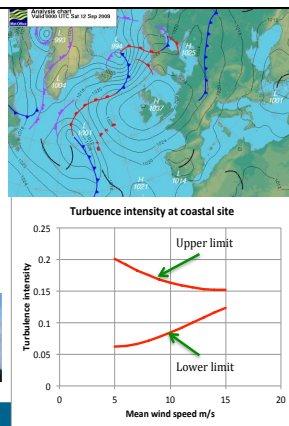
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From low to high wind speeds

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Low wind speeds

- For low wind speeds <10m/s, atmospheric stability (thermal) effects are important
- Stable atmosphere – low turbulence
- Unstable atmosphere – high turbulence



High wind speeds

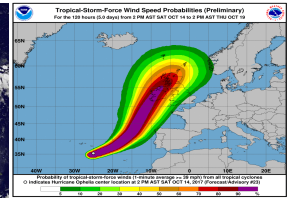
- Tropical cyclones
- Extra tropical cyclones

Hurricane Irma September 2017

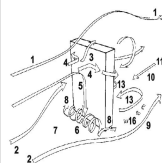


Storm Doris February 2017

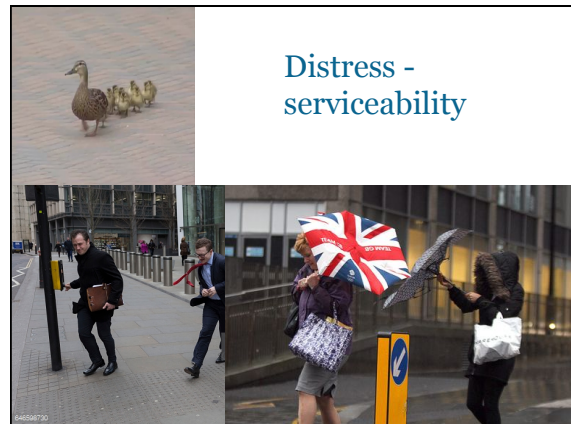
Hurricane / Storm Ophelia October 2017

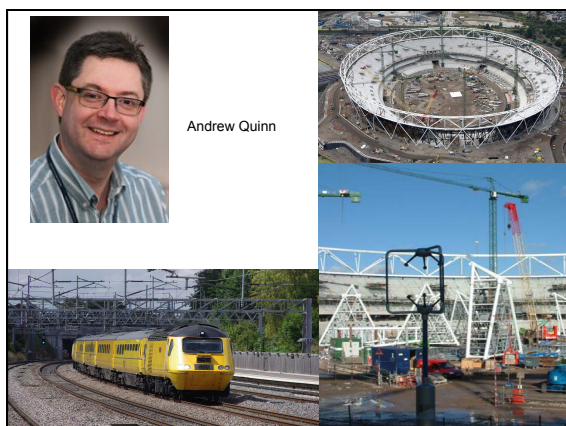


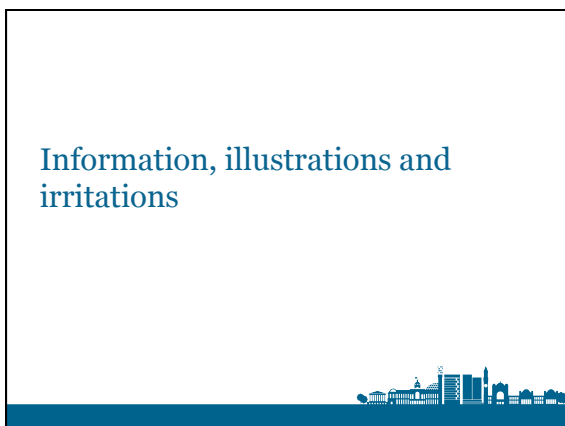
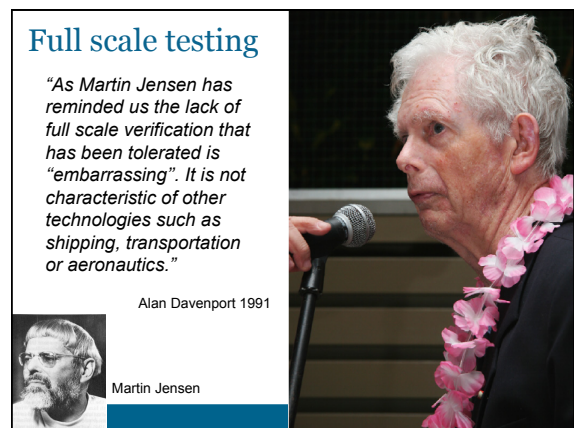
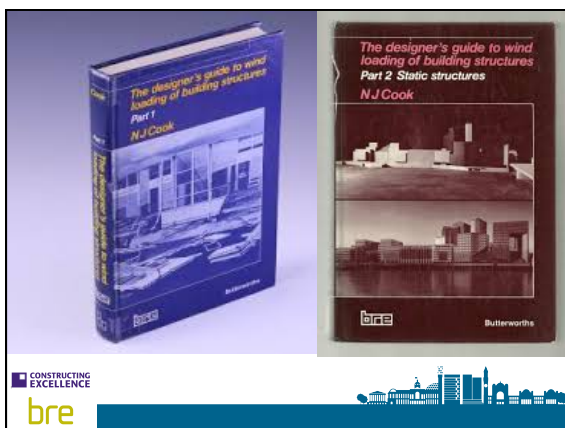
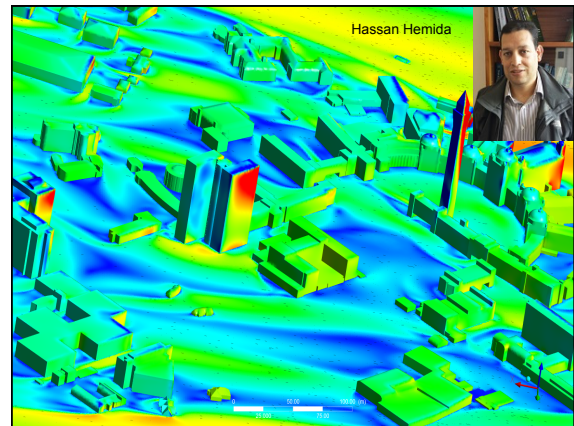
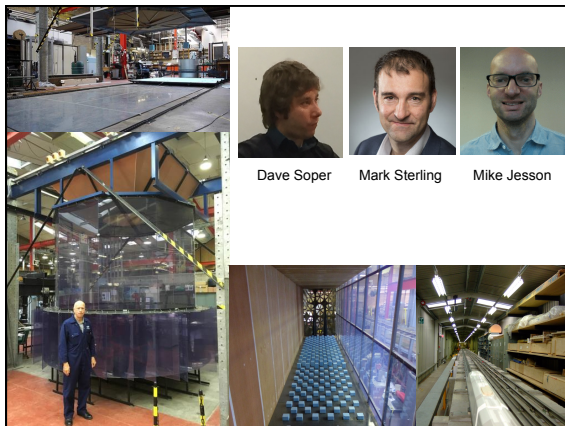
Discomfort - serviceability



Distress - serviceability











John Thornes
Xiaonming Cai


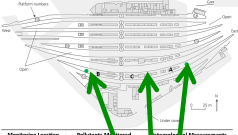


Alice Hickman

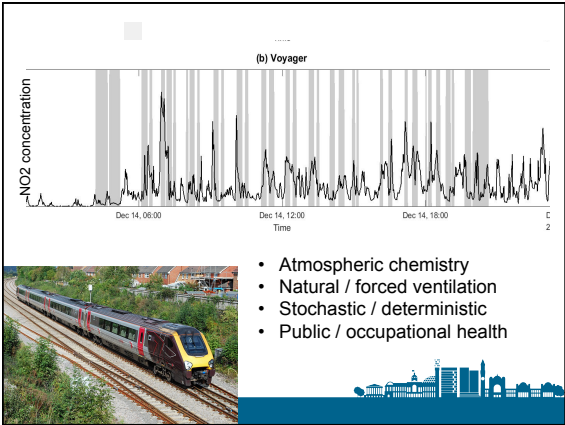
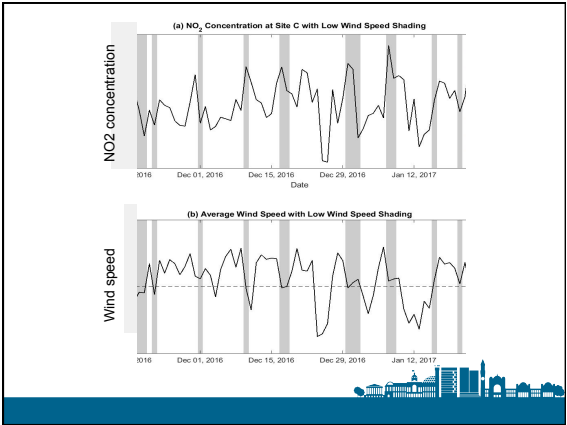
Diffusion tubes NO₂



NO_x, CO₂ and PM



Monitoring Location	Pollutants Measured	Reference Measurement
A 3.5	NO _x , PM	None
C	NO _x , PM, CO ₂	None

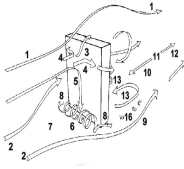


Discomfort


Comfort criteria and London City model



Lawson (2001)		LDDC	
Sitting	5.60m/s, 1% (5)	Pedestrian sitting	4m/s, 5%
Entrance doors	5.6m/s, 6% (6)		
Pedestrian standing	5.6m/s, 6% (6)	Pedestrian standing	6m/s, 5%
Pedestrian walk through	8.25m/s, 4% (8)	Pedestrian walking	8m/s, 5%
People around buildings	10.95m/s, 2% (9)		
Roads and car parks	10.95, 6% (10)	Business walking	10m/s, 5%
Distress	14.1m/s, 0.01%	Distress	15m/s, 0.025%



Tom Lawson



RWDI London City model



Ender Ozcan




RWDI London City model




Ozcan's Penguin Effect



Discomfort - reflections

- Wind comfort is an important aspect of urban serviceability
- Human response needs to be taken into account – exposure to pollutants, wind comfort
- Combination of stochastic and deterministic effects
- Wind speed range where atmospheric stability effects important, particularly on turbulence – should these be taken into account in wind tunnel tests / CFD?
- Is there a need for an agreed approach to comfort acceptability levels?
- Important to consider neighbourhood as well as building scale
- Beaufort Scale should be avoided



Distress


Urban winds project

EPSRC
Engineering and Physical Sciences
Research Council


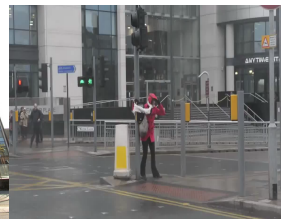


Author	Mean wind speed m/s	Gust wind speed m/s	Notes
Melbourne (1978)		25	Mean plus 3.5sd's
Penwarden	15 to 20		
Hunt (1976)		15 (control of walking) 20 (danger)	Mean plus 3sd's
Lawson (2001)	14.1 to 17.3		
Salgo (1998)	11.9 to 15	22.2 to 27.8	Mean plus 3.5sd's Compilation
Bottema (1992)	10	15 (elderly people) 20 (young people)	Mean plus 2sd's
White (1992)		20	Compilation
L.D.C.C. (in Lawson, 2001)		15	
Peters (1999)		12.5 to 20	Train gust
BRB (1971)		11 (passengers) 17 (trackside workers)	Train gust
CEN (2009)		15.5 (passengers) 22.0 (trackside workers)	Train gust

"A wind of Beaufort Scale 6 can upset a frail old lady. This is not a sexist remark; a lady is specified because she normally presents a greater area of clothing to the wind"
(Tom Lawson, Building Aerodynamics 2001)



Bridgewater Place, Leeds

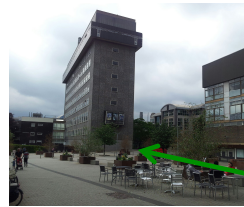
"I'm concerned having heard all the evidence there may be an offence of corporate manslaughter by one or more of the organisations. I'm obliged to adjourn this inquest pending further inquiries by the Crown Prosecution Service"

"I am recommending that Leeds City Council closed the road where Dr Slaney died when wind speeds reached 20 m/s - about 45mph"

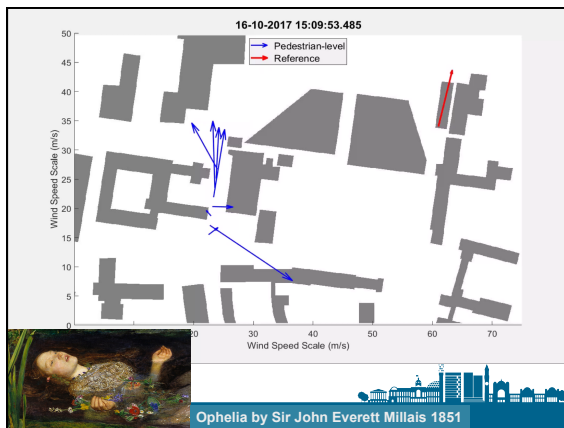
Melanie Williamson, Wakefield Coroner 2014, 2015



Full scale measurements



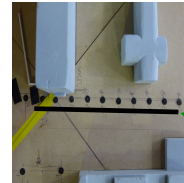
Mike Jesson



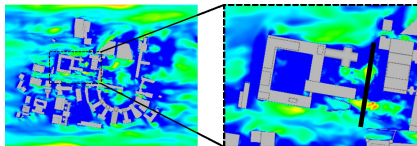
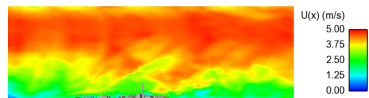
Physical simulation



Mike Jesson



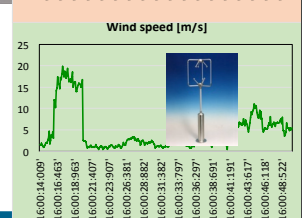
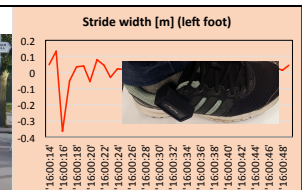
CFD Simulations

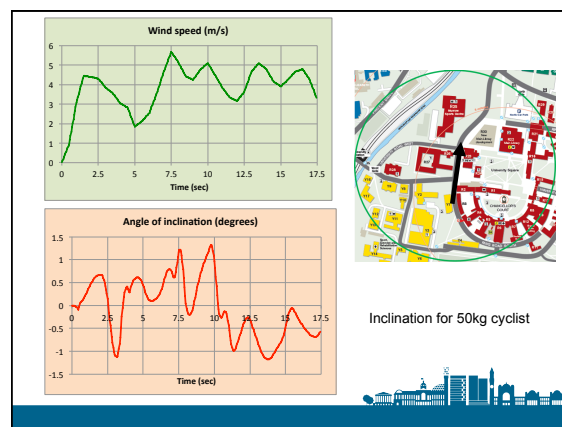
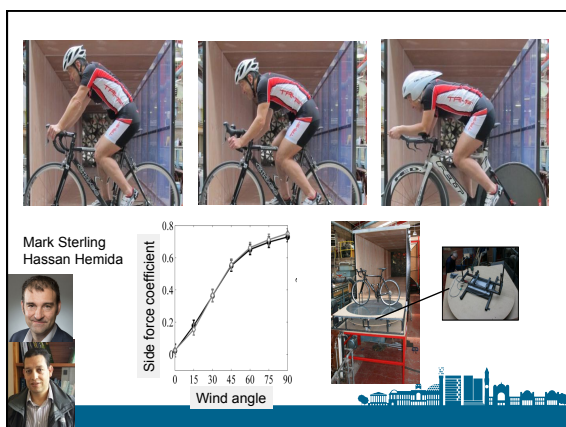


Dominic Flynn
Hassan Hemida



Mingzhe He, Stefanie Gillmeier





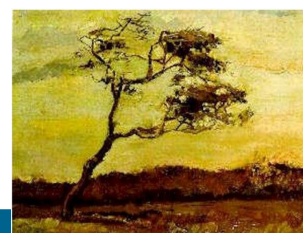
Distress - reflections

- Distress criteria are not well specified yet wind distress remains an important aspect of urban serviceability
- Human variability needs to be taken into account
- Pedestrian level winds are very unsteady and variable – can these be captured by wind tunnel / CFD
- Cycle stability is a growing issue and needs more attention

Disruption

Treefall

A Wind-Beaten Tree
Vincent van Gogh 1883



TREEFALL: Tree Risk Evaluation Environment for Failure And Limb Loss.

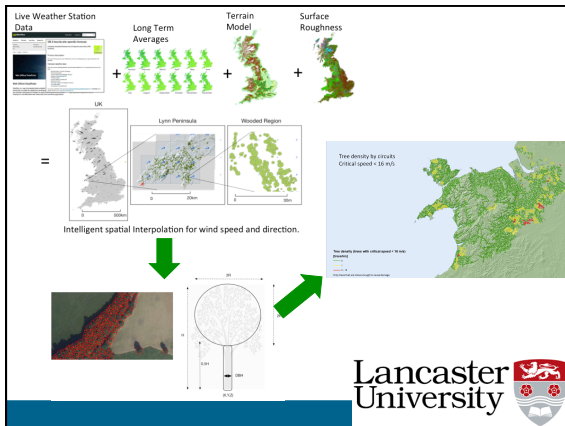


A Spatio-Temporal model to quantify the risk of tree failure to critical infrastructures in severe weather conditions.

Duncan Wyatt Alan Blackburn Dave Gullick

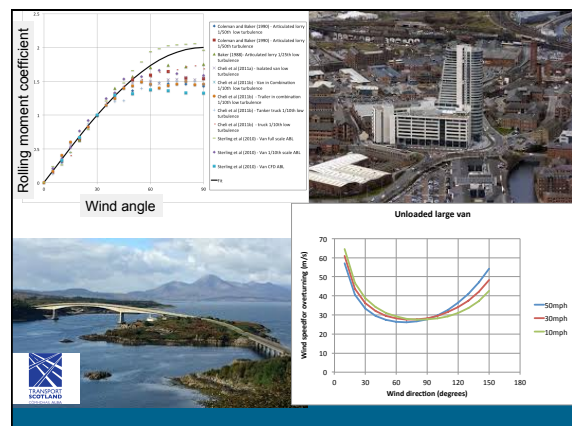
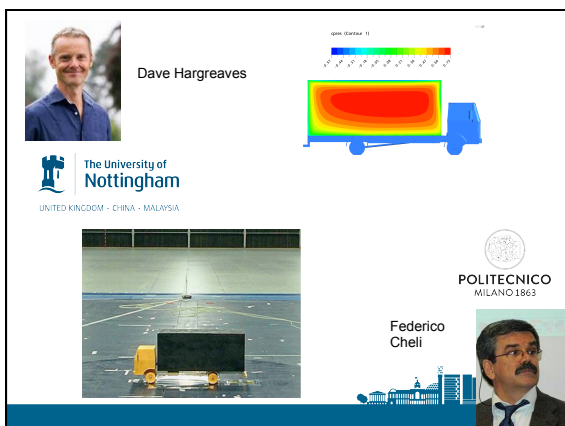
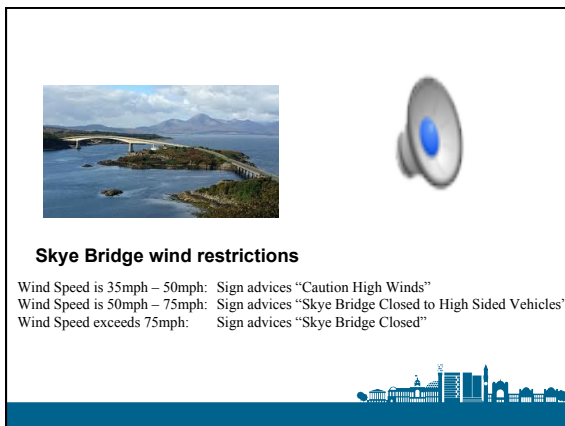


Lancaster University



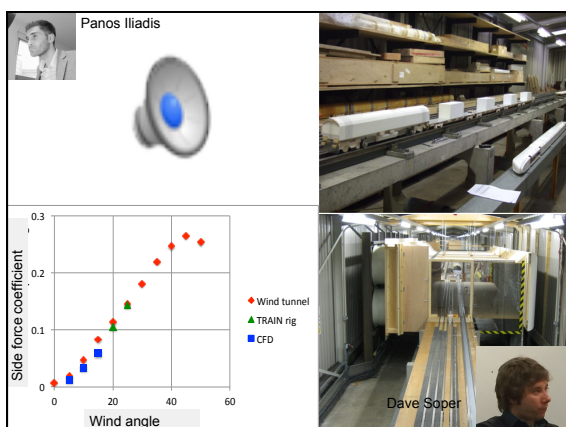
Disruption

Road networks



Disruption

Rail networks



Disruption - reflections

- The disruptive effects of wind are those most commonly experienced by the public
- Stochastic and deterministic components
- Network disruption is almost always at a neighbourhood / regional / national scale - Local failure can have widespread effects
- Operational practicalities can make precise traffic restrictions difficult
- Wind engineering input into network maintenance and development of urban resilience frameworks (including exposure assessment) potentially important – what could be the business case for this?

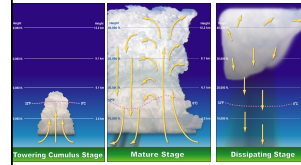


Damage

Small scale storm systems



Thunderstorms / Downbursts

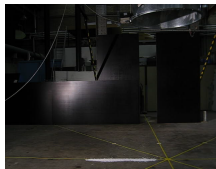


le shuttle



Mark Sterling Mike Jesson

Physical simulation



Tornadoes

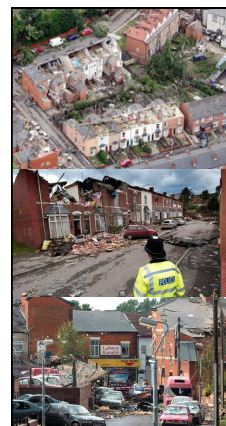
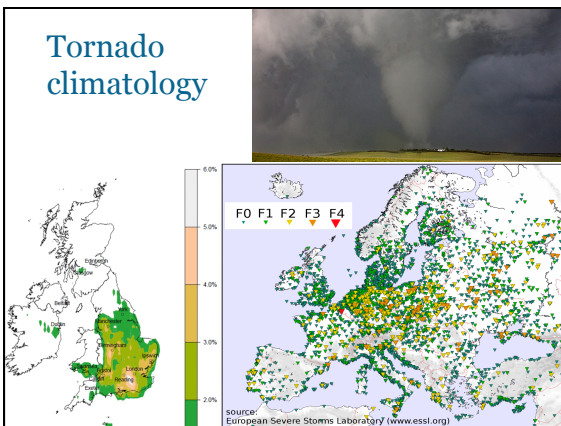
*This year came dreadful fore-warnings over the land of the Northumbrians, terrifying the people most woefully: there were immense sheets of light rushing through the air, and **whirlwinds**, and fiery, dragons flying across the firmament.*



Anglo Saxon Chronicle AD 793



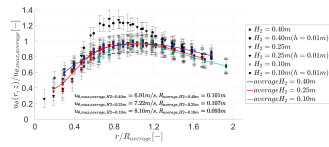
Tornado climatology



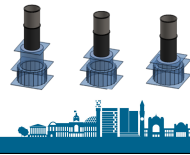
- Tornado damage caused by direct wind loads, pressure loads and debris impact.
- Effects usually very localised.
- Community resilience can be severely challenged.



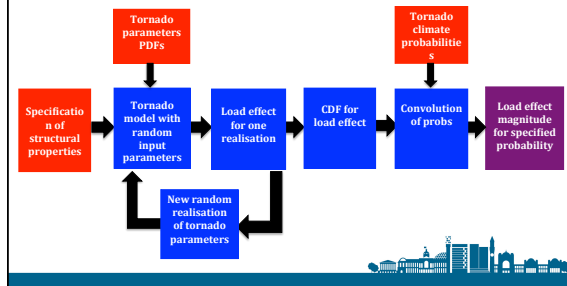
Tornado vortex generator scaling



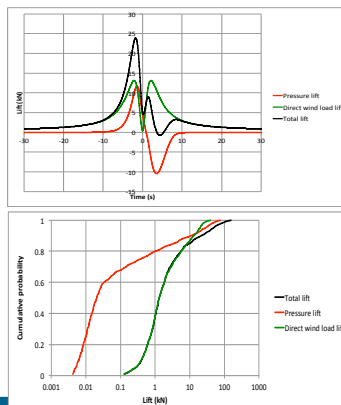
Mark Sterling Hassan Hemida Steffi Gilmeier



Conceptual model of tornado wind loading



Tornado induced lift on pitched roof building



Damage

Wind borne debris

EPSRC
Engineering and Physical Sciences
Research Council

"the streets lay so covered with Tiles and Slates, from the Tops of the Houses, especially in the Out-parts, that the quantity is incredible, and the Houses were so universally stript, that all the Tiles in Fifty Miles round would be able to repair but a small Part of it" Daniel Defoe 1703



Maeso Tachikawa



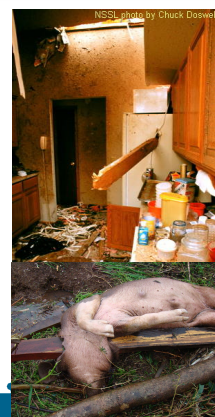
compact object

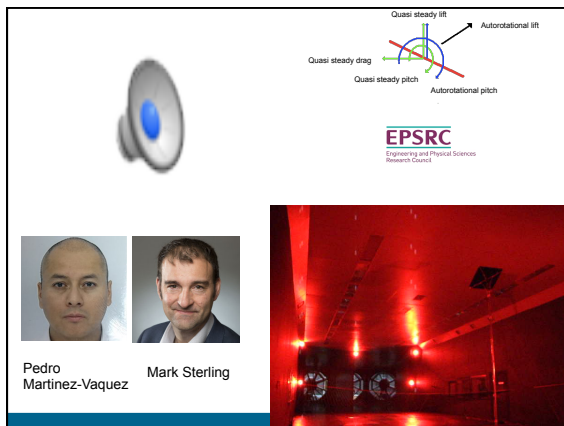


sheet, plate

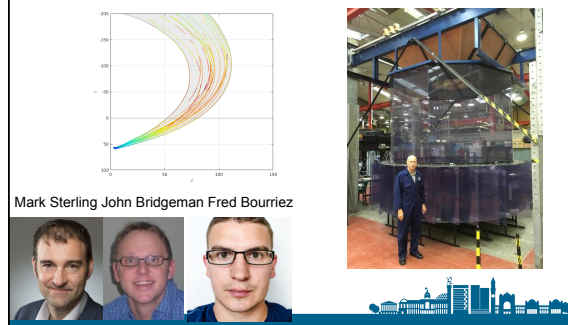


rod, pole

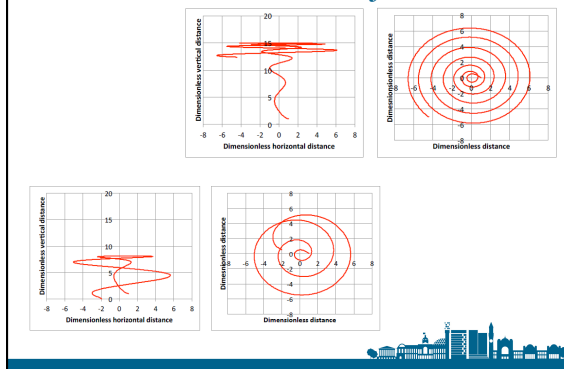




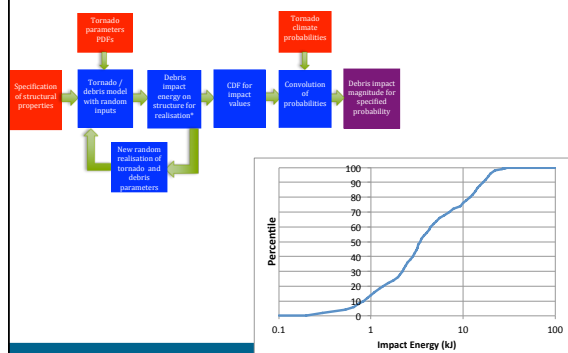
Measurement of tornado debris trajectories



Calculation of debris trajectories



Debris impact loading in tornadoes



Damage - reflections

- Wind Engineering design is about much more than the design for synoptic gusts
- Smaller storm types can cause localised damage and disruption and severely impact local communities
- Robust design methodology still to be developed for many storm types to ensure structural resilience
- Need for loading data for a range of non-synoptic winds – from Downburst generators, Tornado Vortex Generators, CFD?
- Debris impact loads need consideration to ensure building envelopes do not fail

~~Conclusions~~

Take Aways

