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The 7th European Aeronautics Days

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The 7th European Aeronautics Days

BUCOLIC
Characterisation of Buffet on a Civil Aircraft Wing

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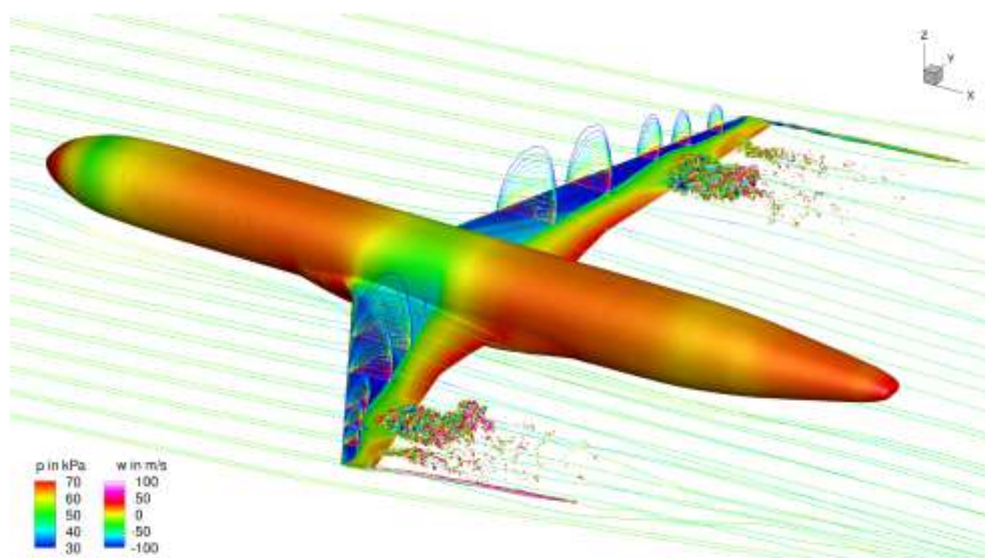
BUCOLIC

- CleanSky project
  - SFWA (Smart Fixed Wing) ITD, Technology Stream 6
  - BUCOLIC = "**BU**ffet **CO**ntro**L** of Transon**IC** Wings"
  - Aircraft Research Association Ltd and Liverpool University



Buffet

- What is 'buffet' ?
  - aerodynamic excitation due to separated flow
    = critical flight envelope limit = wing design constraint
- What causes it ?
  - straightforward at low-speed = onset of flow separation
  - shock-induced buffet at transonic cruise conditions more complex
    - 2D aerofoil buffet reasonably well understood
    - 3D wing buffet not well understood … additional flow mechanism(s)?
- How can it be controlled ?
  - wing design
  - active flow control
  - passive flow control

→ *design still dependent on semi-empirical prediction methods*

Project Objectives

- Programme objectives:
  - increased understanding of the flow physics of 3D transonic wing buffet
  - increased understanding of the parameters that affect buffet onset
  - improved understanding of buffet control devices to improve performance of next generation wings
  - development of an industrialised CFD method able to predict buffet for routine use in designing wings with control devices

- This presentation will focus on the experimental aspects of the project

WP2 Wind Tunnel Testing

- Work package aims
  - to modify an existing model to incorporate additional instrumentation and buffet control devices
  - to investigate the factors which govern the onset and development of wing buffet
  - to investigate the effectiveness of buffet control devices and provide a database of experimental data to validate the CFD methods

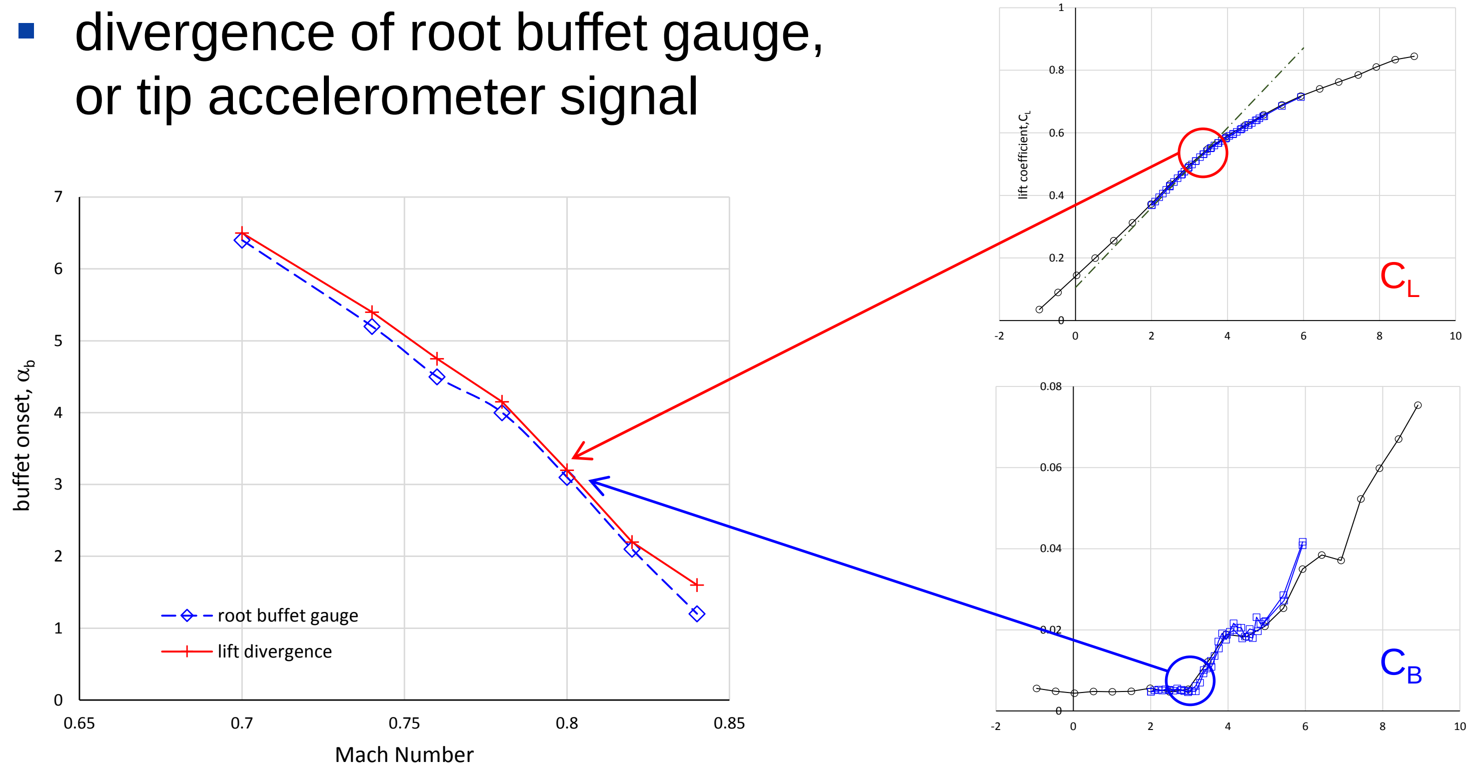
- ARA 2.74m × 2.44m Transonic Wind Tunnel
- representative ‘turbulent’ wing design
- comprehensive unsteady instrumentation
  - conventional force and pressure transducers +
  - industrialised Dynamic Pressure Sensitive Paint (DPSP)

Wind Tunnel Model

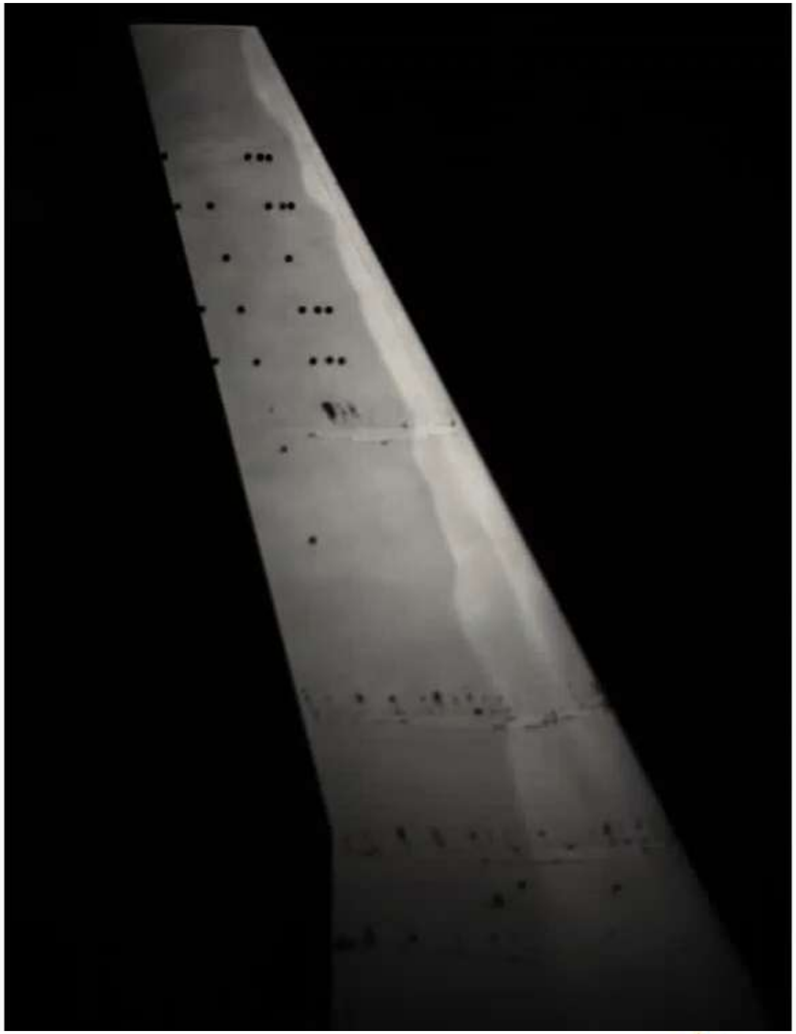
- Existing ARA half-model +
- Dedicated buffet instrumentation
  - pressure transducers
  - accelerometers
  - buffet gauge etc
- Dynamic PSP
  - upper and lower surfaces
  - 4kHz sample rate
- Passive buffet control
  - vortex generators on outboard wing
  - full (32) and sparse (8) arrays
- $M = 0.7\text{-}0.84$, $\alpha = 0\text{-}8^\circ$
  - cruise buffet limits

Buffet Envelope

- ‘breaks’ in static aerodynamic characteristics
  - standard prediction methodology in project design
- Dynamic model response
  - divergence of root buffet gauge, or tip accelerometer signal



Dynamic Pressure Sensitive Paint

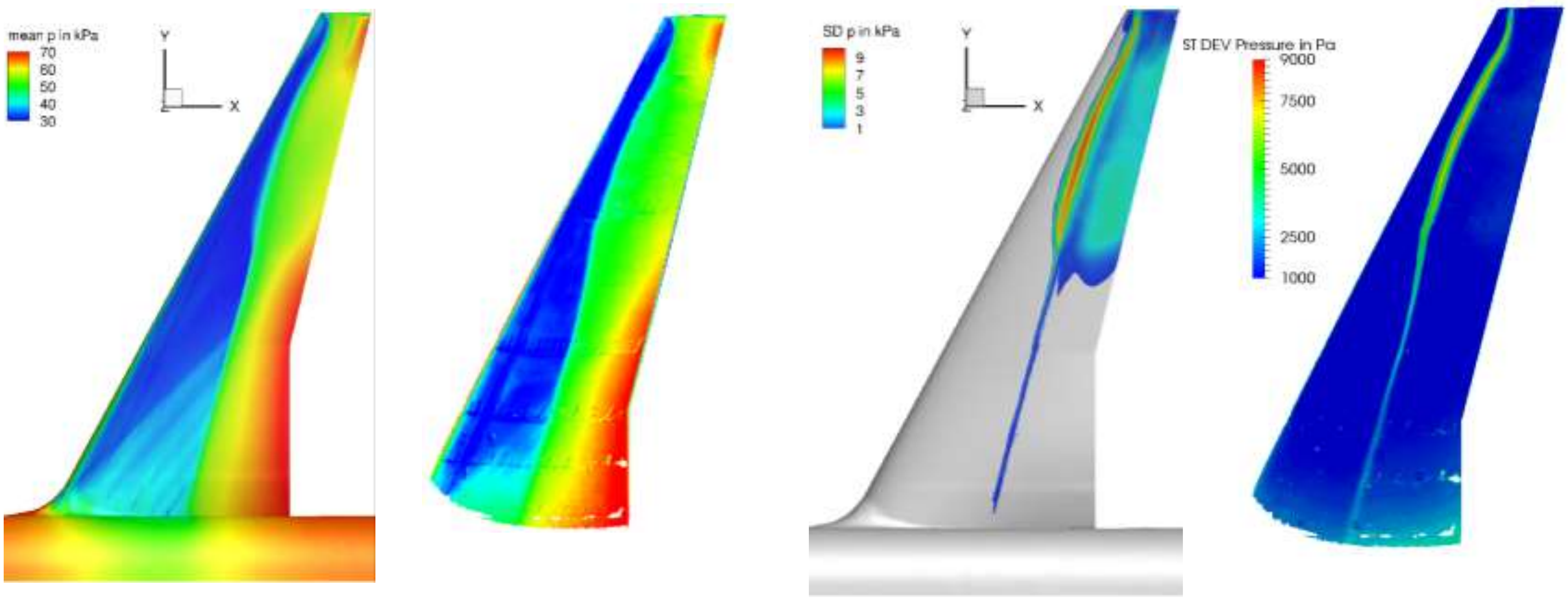


Dynamic Pressure Sensitive Paint

- Near real-time imaging
  - can assess unsteady flow features during test
- Data rather more complex than anticipated
  - large-scale spanwise and small-scale chordwise flow structures
  - intermittent, with multiple time-scales
- *Would have been impossible to interpret using discrete pressure transducer data*
  - limited spatial coverage
  - frequency domain analysis problematic due to intermittency
- Comprehensive spatial coverage from DPSP makes it a breakthrough capability for buffet studies
  - frequency and time-domain analysis, cross-correlations etc
  - volume of data becomes a problem!

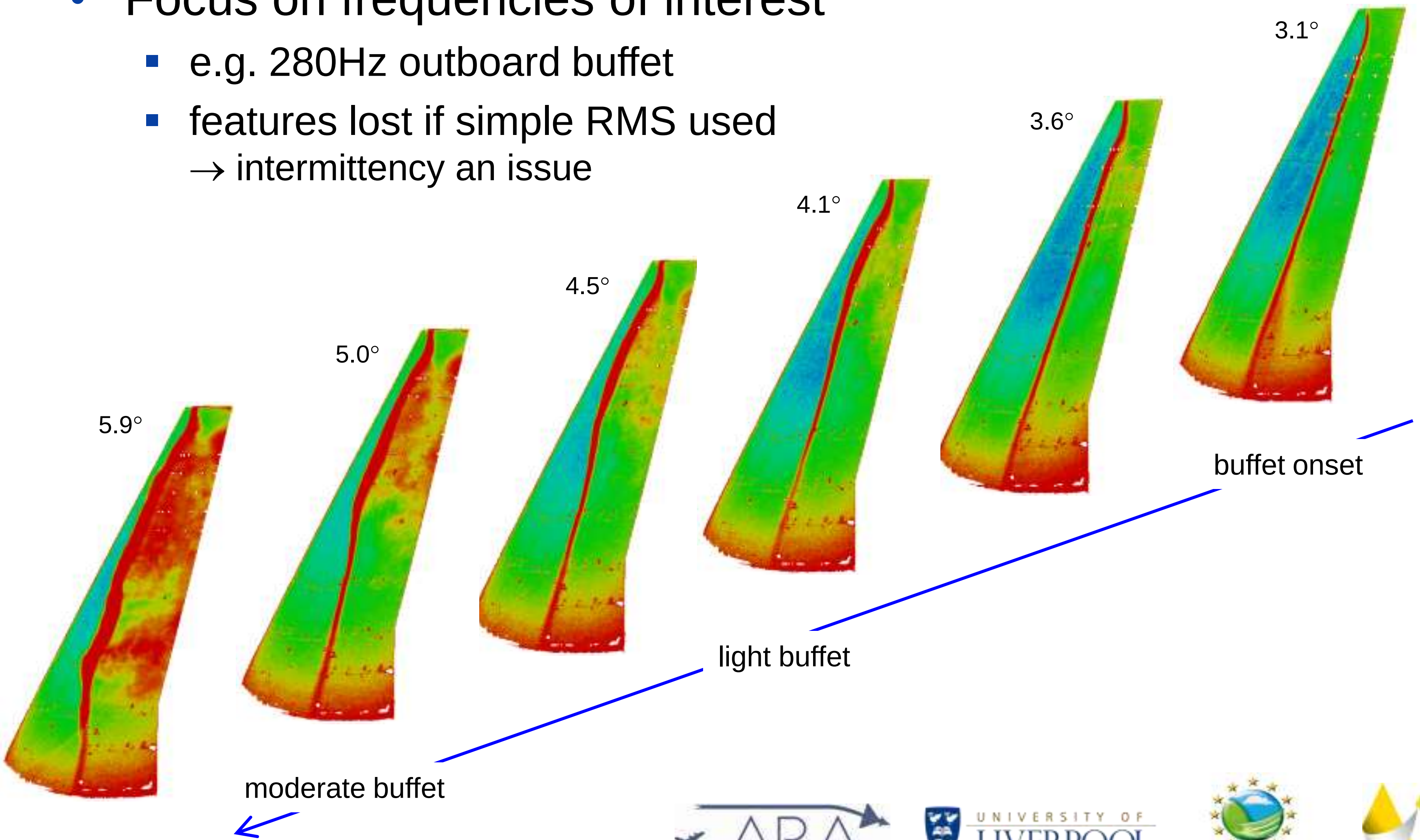
Good Comparison with CFD

- DES (UL) vs DPSP (ARA)
  - mean pressures
  - RMS pressures
  - time histories

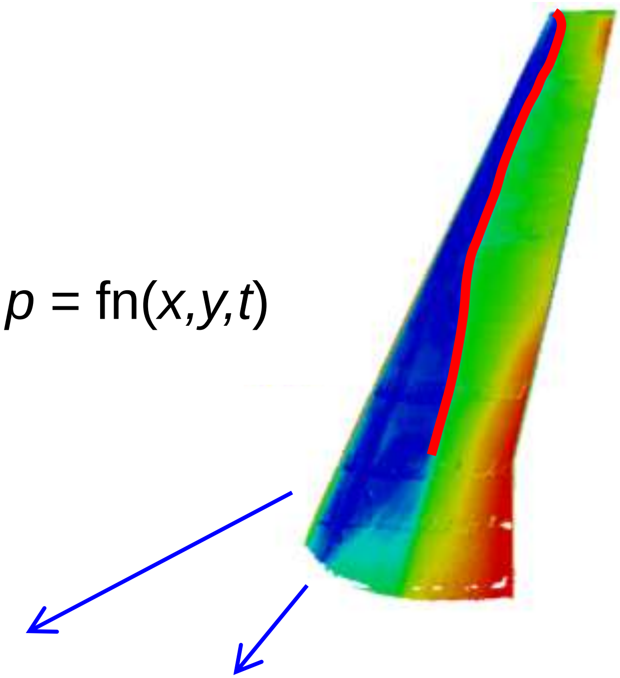


Typical Frequency-Domain Analysis

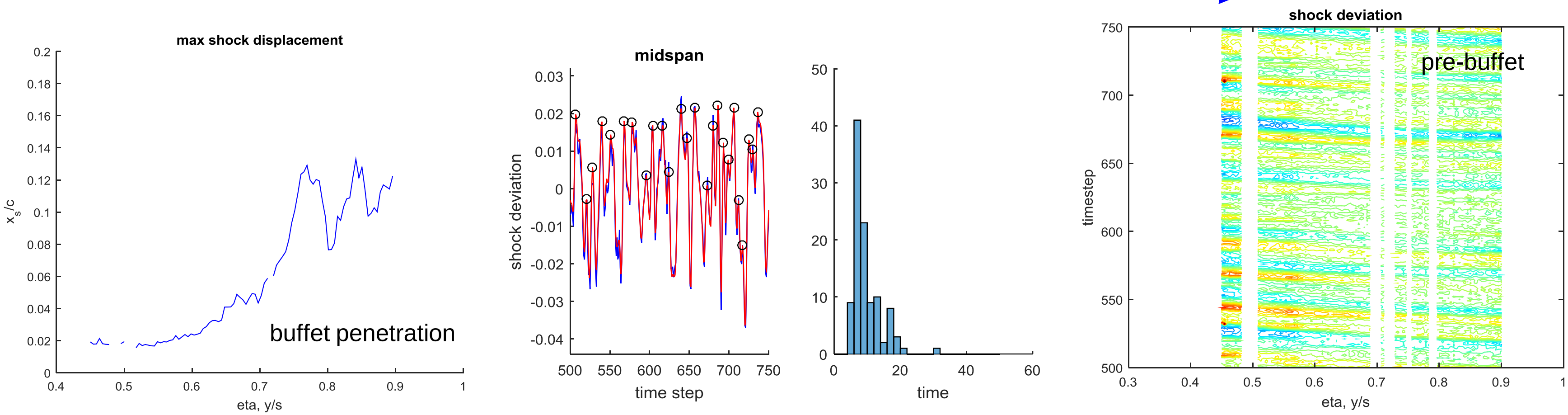
- Focus on frequencies of interest
  - e.g. 280Hz outboard buffet
  - features lost if simple RMS used
    → intermittency an issue



Typical Time-Domain Analysis



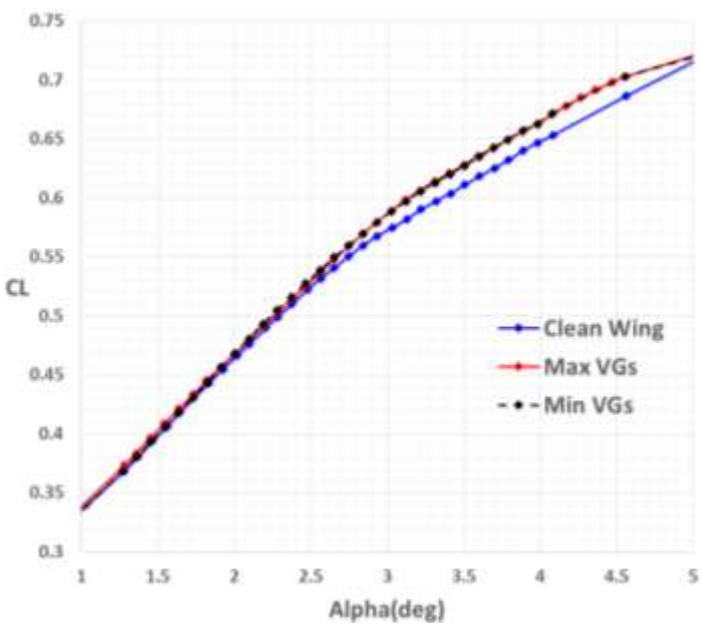
- Need to simplify 3D data
  - e.g. extract shock position = fn(y,t) from p = fn(x,y,t)
- Wide range of possible analyses
  - statistics
  - time/space contours
  - cross-correlations, etc

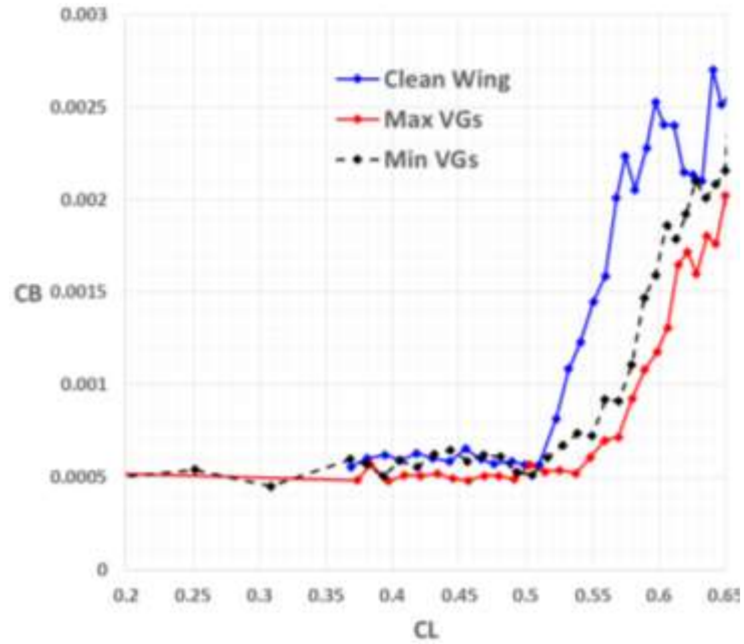


- Highlights differences between 2D and 3D shock buffet

Effect of Vortex Generators

- Delayed lift break, delayed buffet onset
  - *'sparse' VG array almost as effective as 'full' array*
- Complex effects on unsteady flow structures
  - insights from DPSP invaluable in understanding mechanism(s)
  - improved basis for design of efficient passive flow control systems





Conclusions

- Extensive experimental database for 3D buffet excitation
  - demonstration of industrialised DPSP in a large wind tunnel
    $\rightarrow$ previously unavailable spatial / time resolution at transonic conditions
  - characterisation of chordwise and spanwise flow features that would not be possible with discrete transducers
- Frequency domain analysis constrained by intermittent nature of critical buffet flow features
  - extent and location of separated flow regions, shock position
- Time domain analysis very revealing
  - needs careful pre-processing to reduce order of dataset
  - spatial and time correlations give new perspectives on the nature of 3D wing buffet mechanisms
    $\rightarrow$ *will feed into design optimisation of active and passive buffet control concepts*