UNIVERSITY OF CAMBRIDGE 800 YEARS 1209 ~ 2009

Institute for Aviation and the Environment

Modelling Performance and Emissions from Aircraft for the AIM project

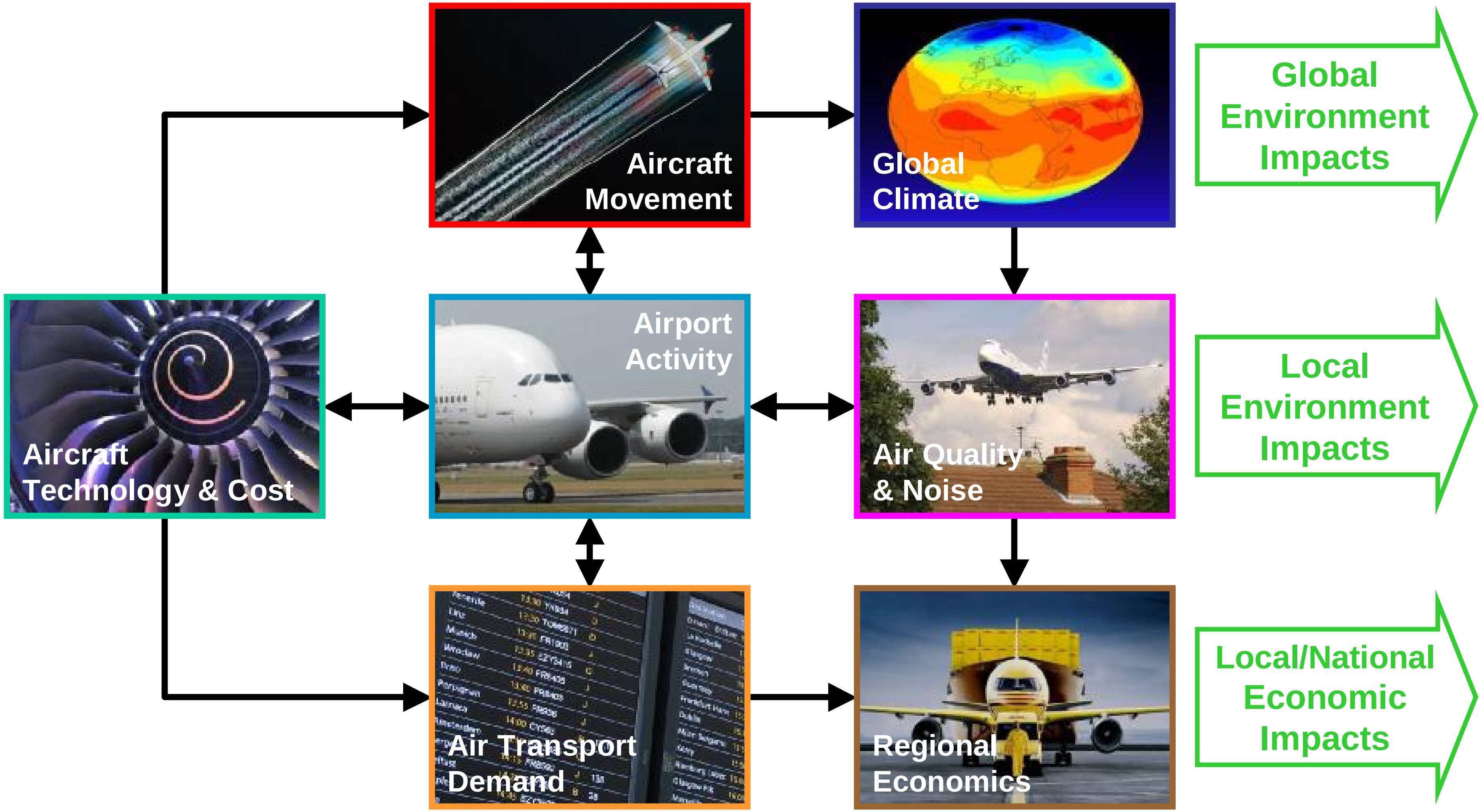
María Vera-Morales, Cesare Hall

Institute for the Aviation and the Environment
University of Cambridge

Outline

- Introduction
- Methodology
  - Airframe aerodynamics
  - Engine Modelling
  - Operations
  - Emissions Modelling
- Validation
  - Engine Modelling
  - Constant level cruise
- Applications
  - Constant level cruise
  - Stepped cruise
  - Full mission
- Conclusions

Introduction



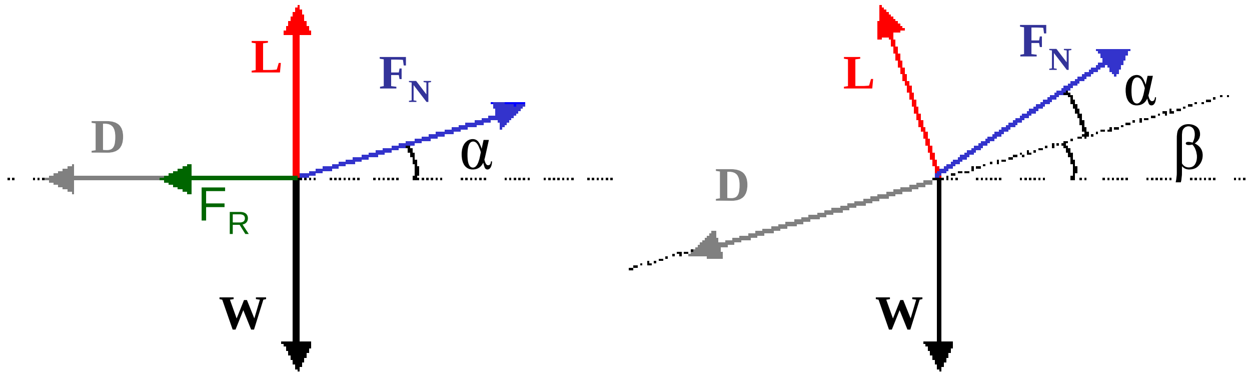
www.AIMproject.aero

UNIVERSITY OF CAMBRIDGE

AIM

Methodology: PESO

Performance and Emission Simulations of flight Operations (PESO)



Runway Airborne

$$L(a) + F_N \sin a - W \cos b = a_{nor} Mass$$

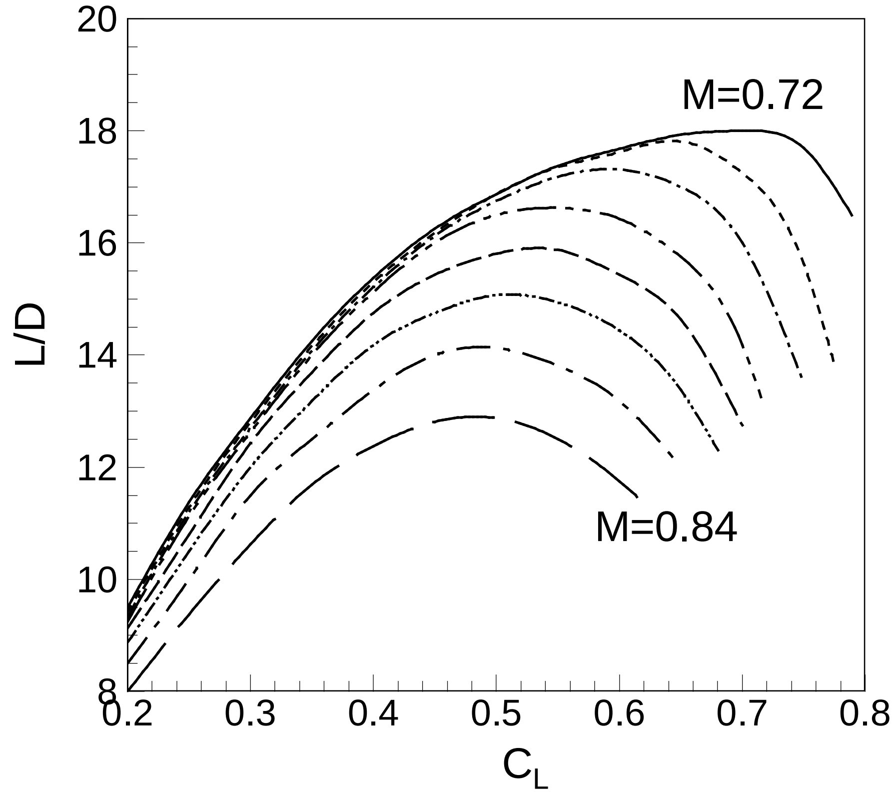
$$-D(a) + F_N \cos a - W \sin b = a_{long} Mass$$

UNIVERSITY OF CAMBRIDGE

AIM

Methodology: Airframe Aerodynamics

- High speed L/D



- C_L vs. Angle of Attack

Methodology: Engine Modelling

- Engine performance $= f(P_a, T_a, M_0, \dot{m}_f)$
- Engine performance parameter $= f(P_a, T_a, M_0)$

If final nozzles are choked → $f(P_0, T_0)$

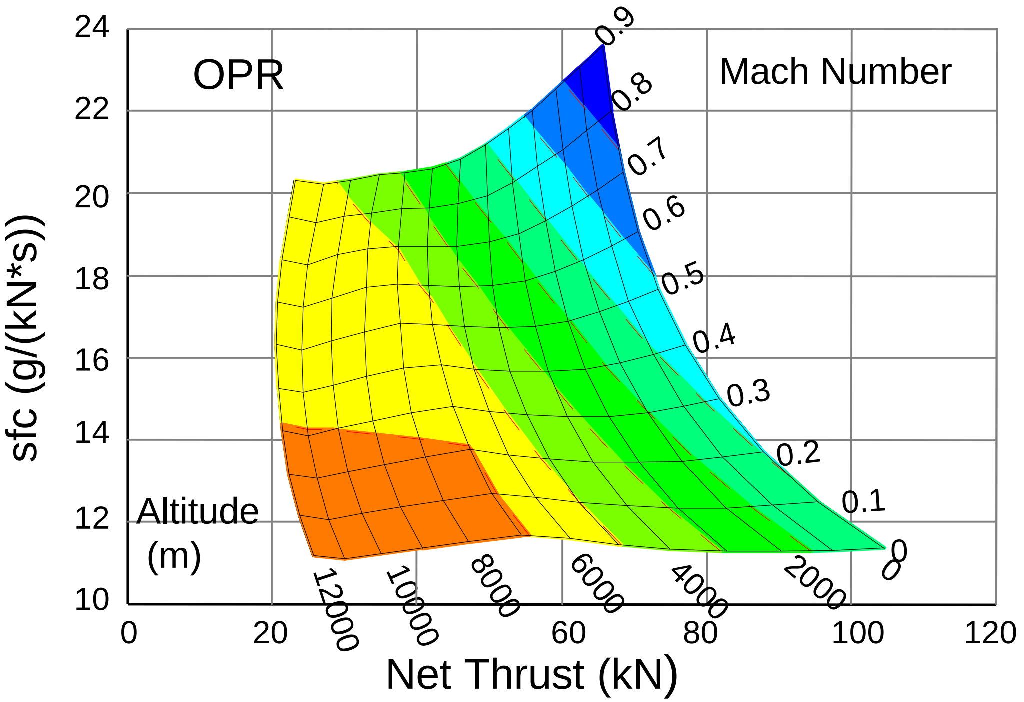
$$F_N = F_G - \dot{m}_a V$$

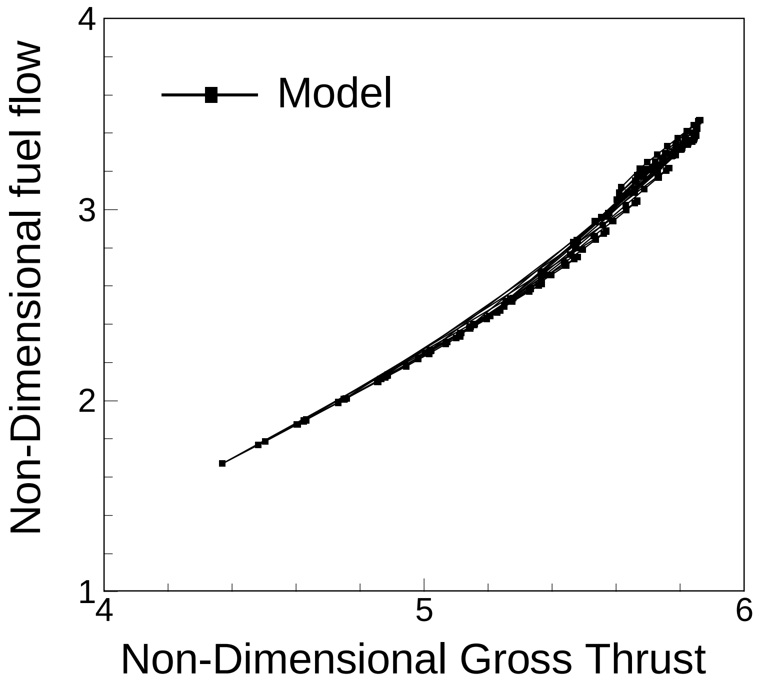
$$\overline{\dot{m}}_f = \frac{\dot{m}_f LCV}{l^2 P_{02} \sqrt{C_p T_{02}}}$$

$$\overline{F}_G = \frac{F_G + P_a A_N}{l^2 P_{02}}$$

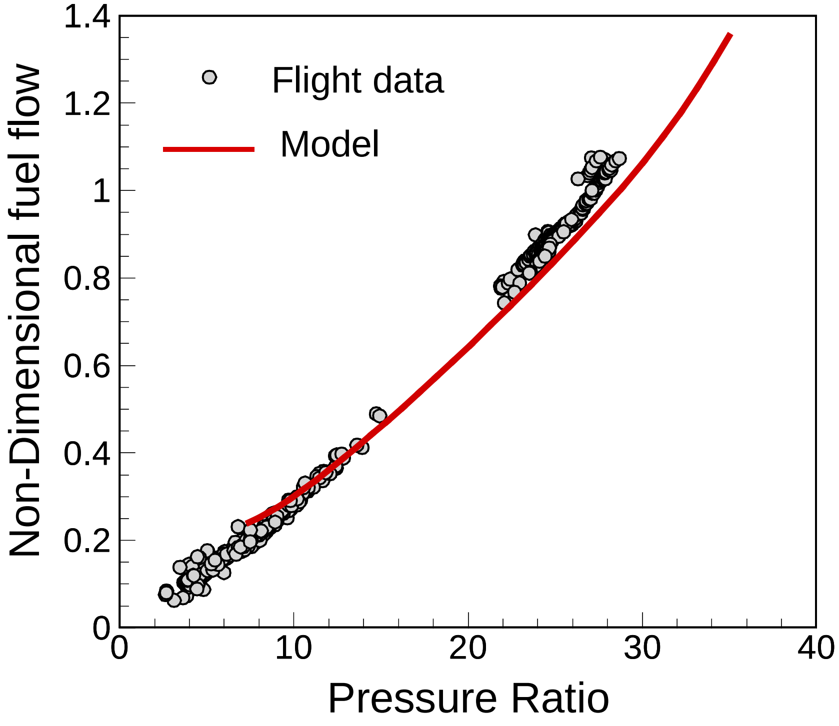
Methodology: Engine Modelling

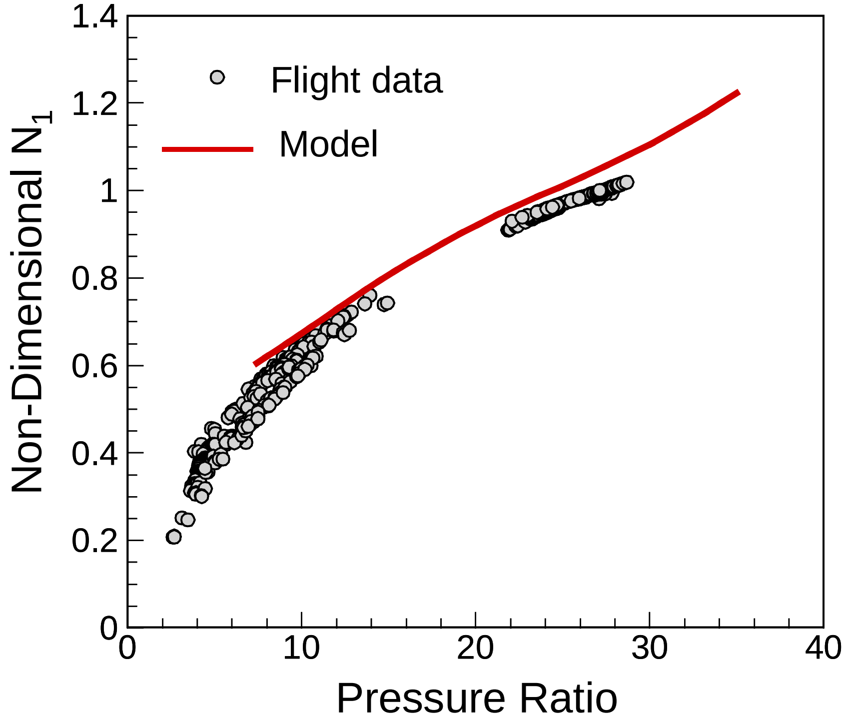
Engine model: GasTurb





Methodology: Engine Modelling

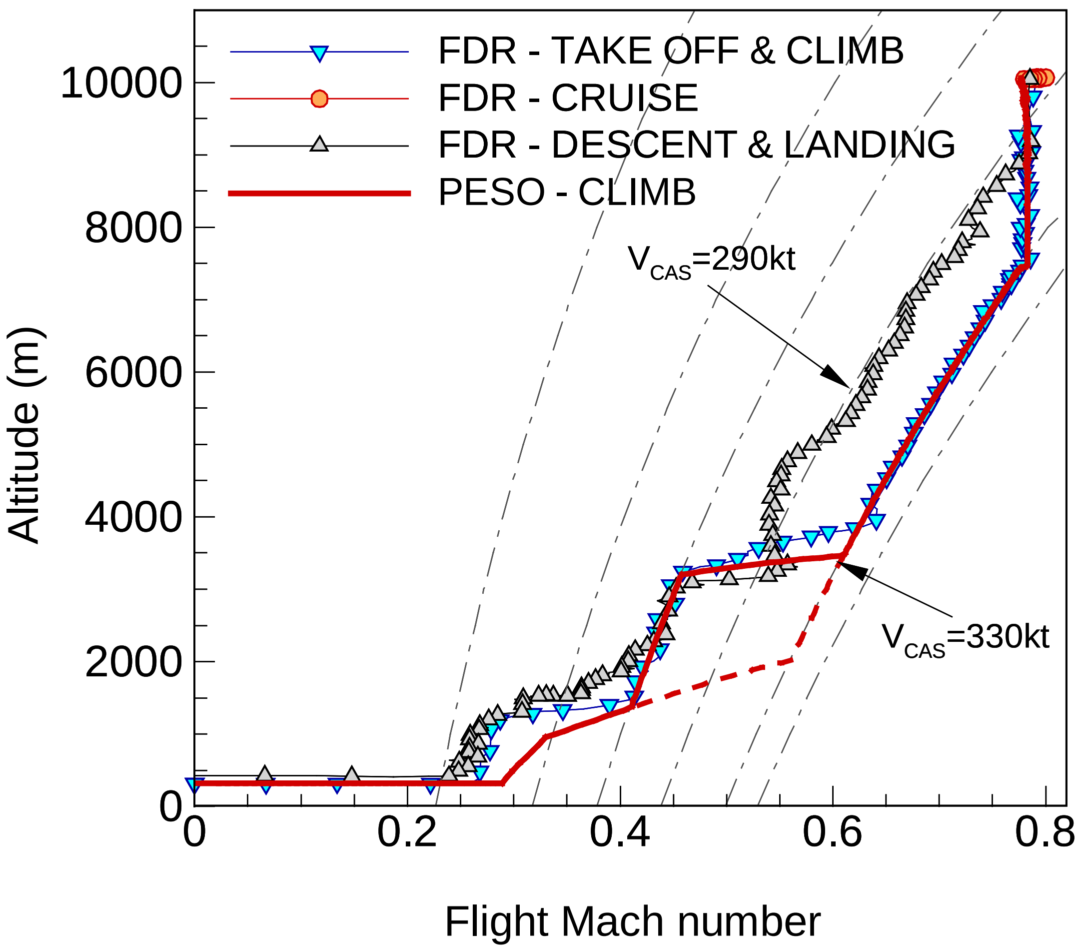




UNIVERSITY OF CAMBRIDGE

AIM

Methodology: Operations

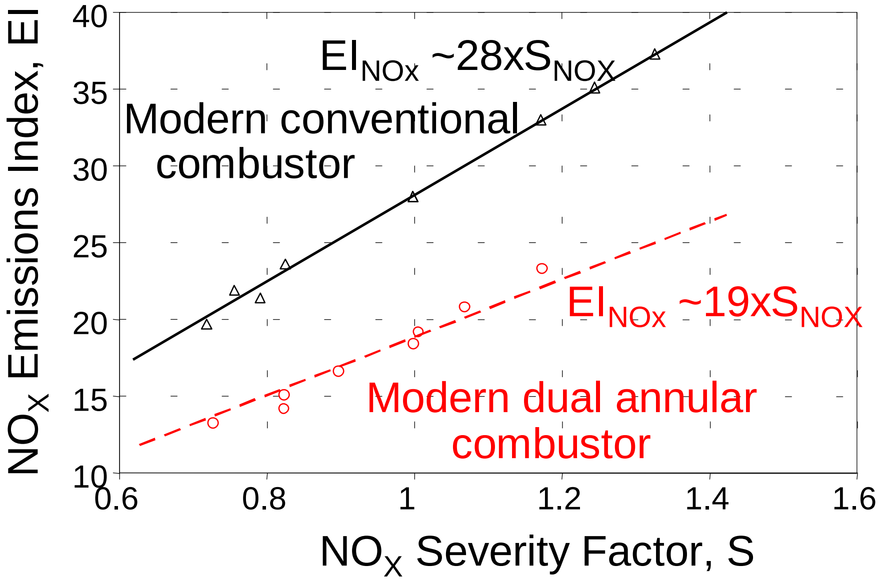


Methodology: Emissions Modelling

$$P = EI_P \cdot sfc \cdot F_N$$

$$EI_{NOx} = C \cdot S_{NOx}$$

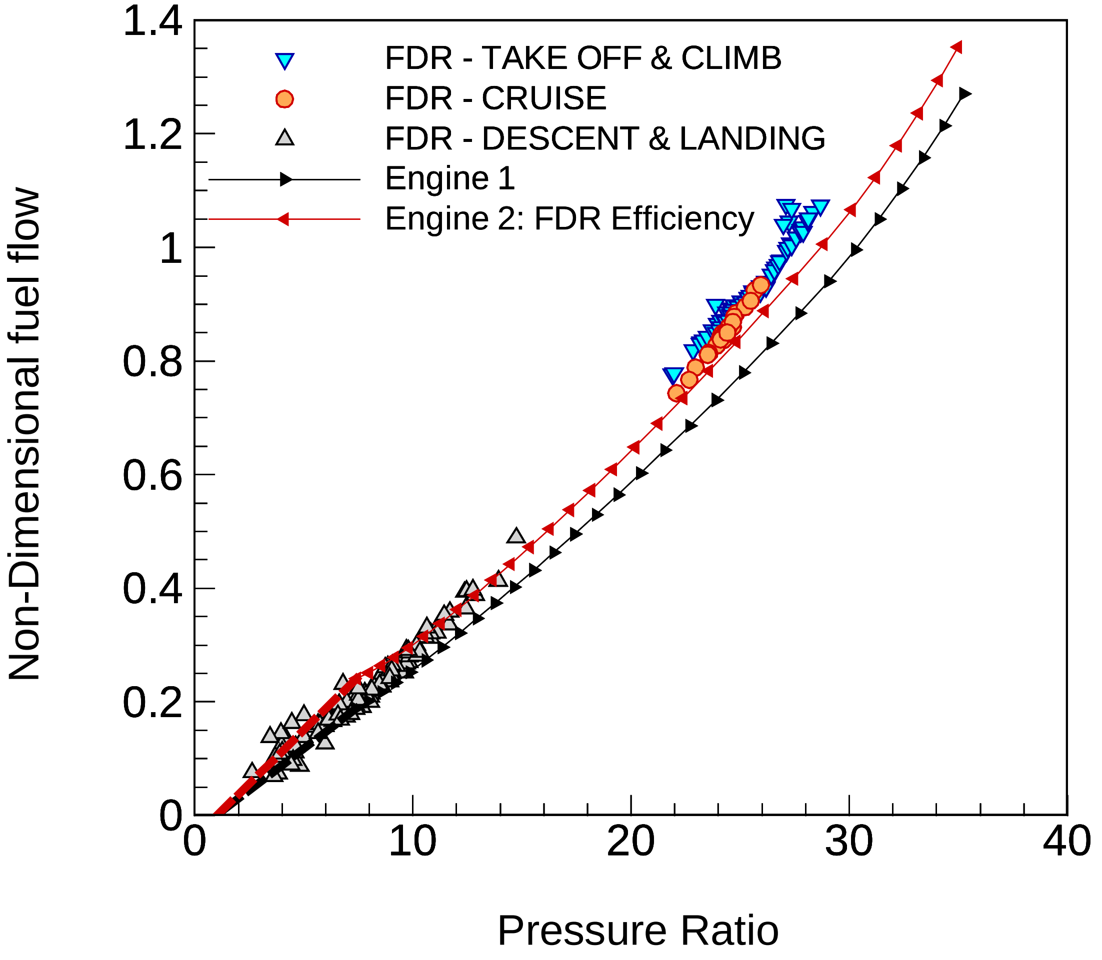
ICAO f(technology)



f(thermodynamics)

$$S_{NO_X} = \left(\frac{P_{03}}{2965000} \right)^{0.4} + e^{\left(\frac{T_{03} - 826}{194} + \frac{6.29 - 100\,war}{53.2} \right)}$$

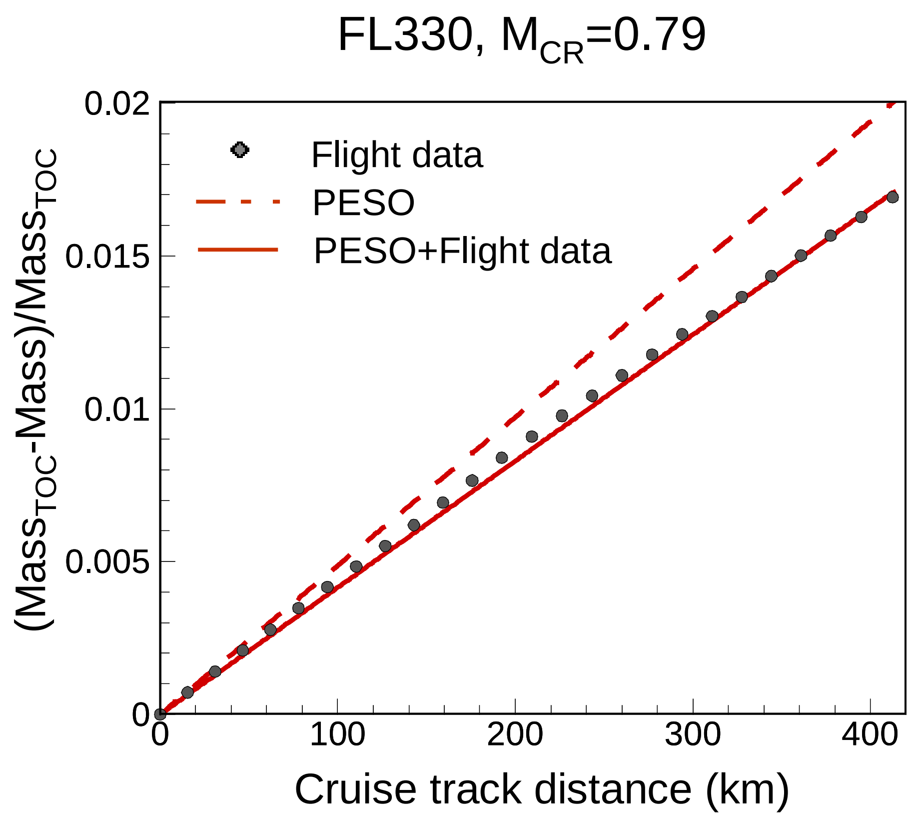
Validation: Engine Modelling



UNIVERSITY OF CAMBRIDGE

AIM

Validation: Constant Level Cruise



$$\frac{L}{D} \times \frac{1}{sfc} = \frac{-s_{CR}\, g}{V \ln\left(\frac{W_{end}}{W_{start}}\right)}$$

UNIVERSITY OF CAMBRIDGE

AIM

Validation: Constant Level Cruise

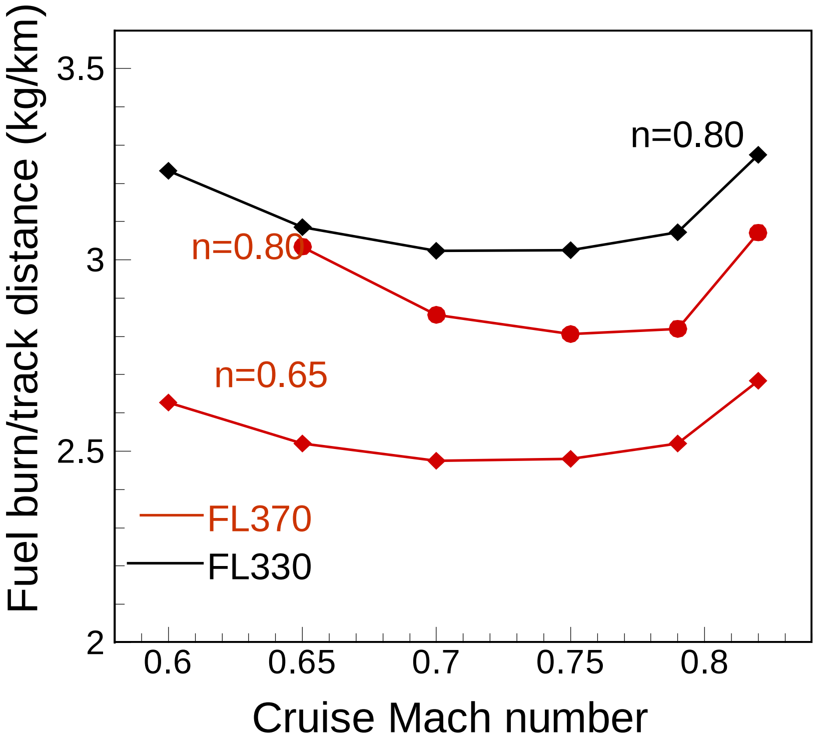
M_{CR}=0.78; $Mass_{TOC}$/MTOW=0.72; s_{CR}=235km

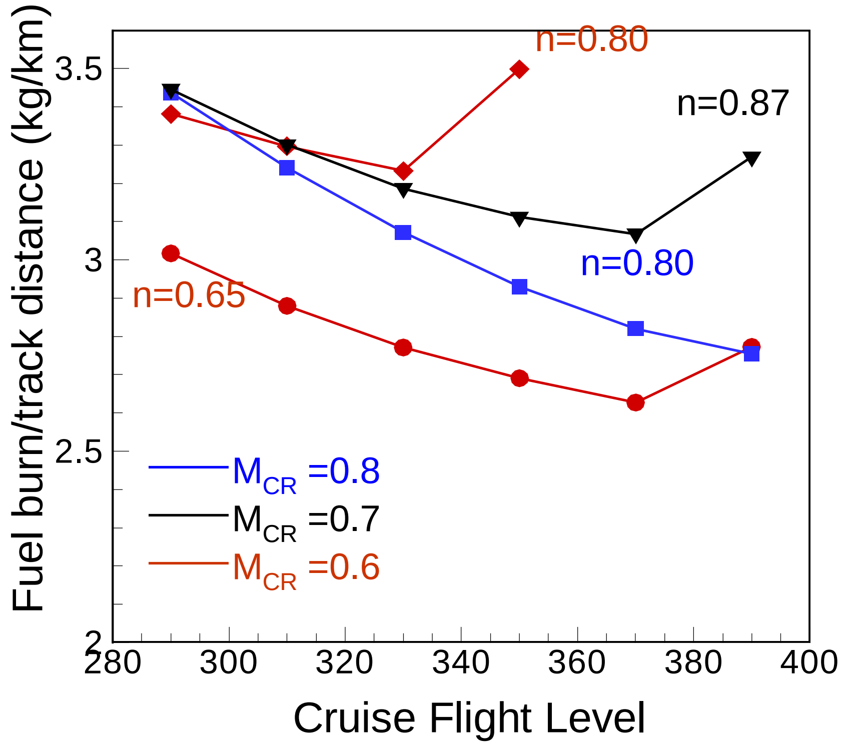
	Flight Data		*PESO*	
	FL320	*FL390*	*FL320*	*FL390*
Fuel burn kg/km	**3.51**	**2.37**	**3.04**	**2.53**
L/D	**13.0**	**18.4**	**14.8**	**16.8**

Applications: Constant Level Cruise

$n = M_{TOC}/MTOW$

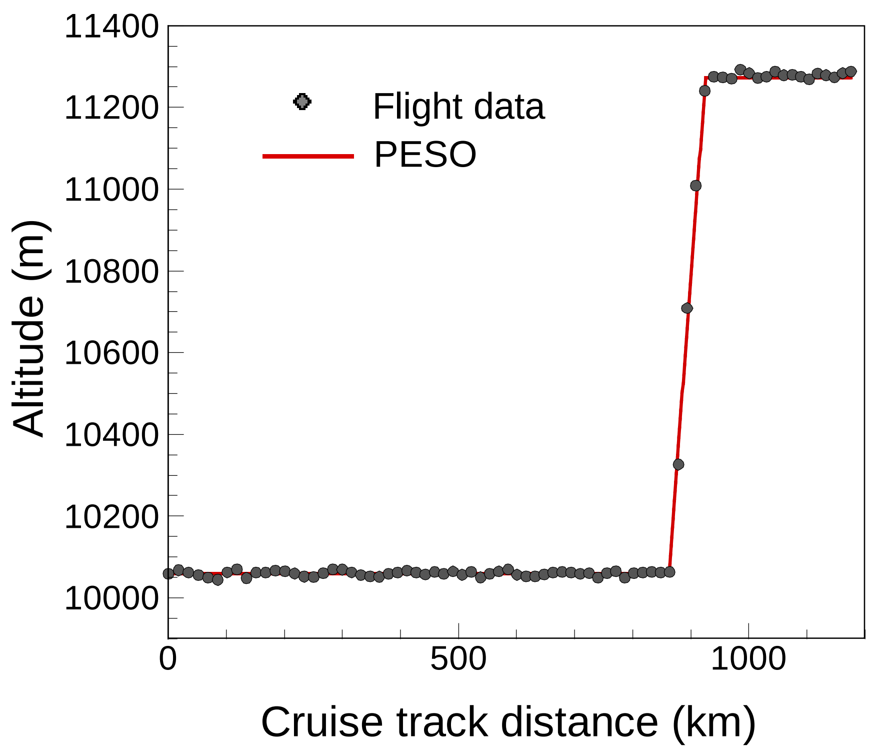
Cruise length=600km

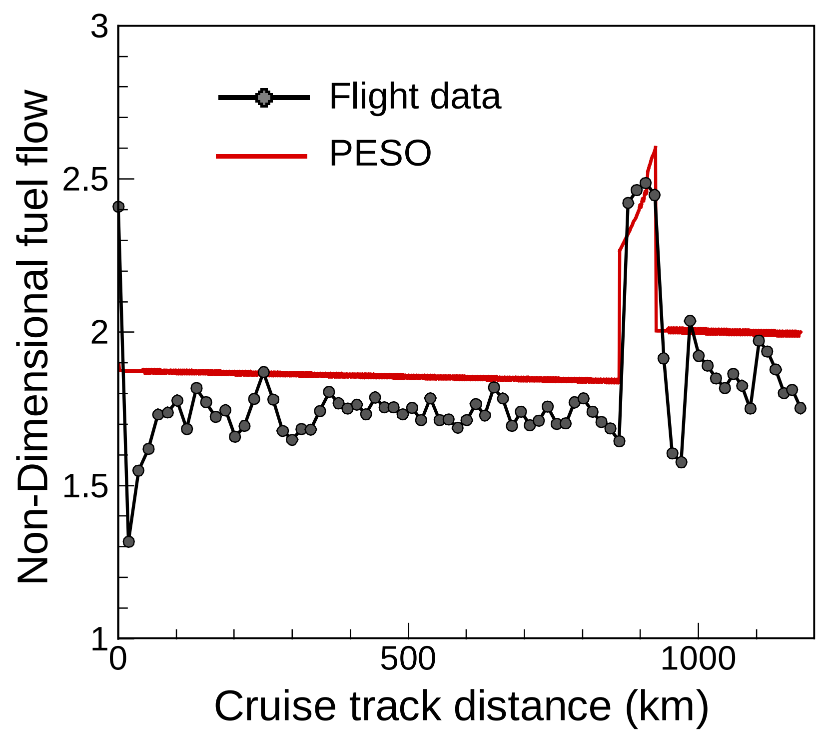




Applications: Stepped Cruise

M_{CR}=0.78

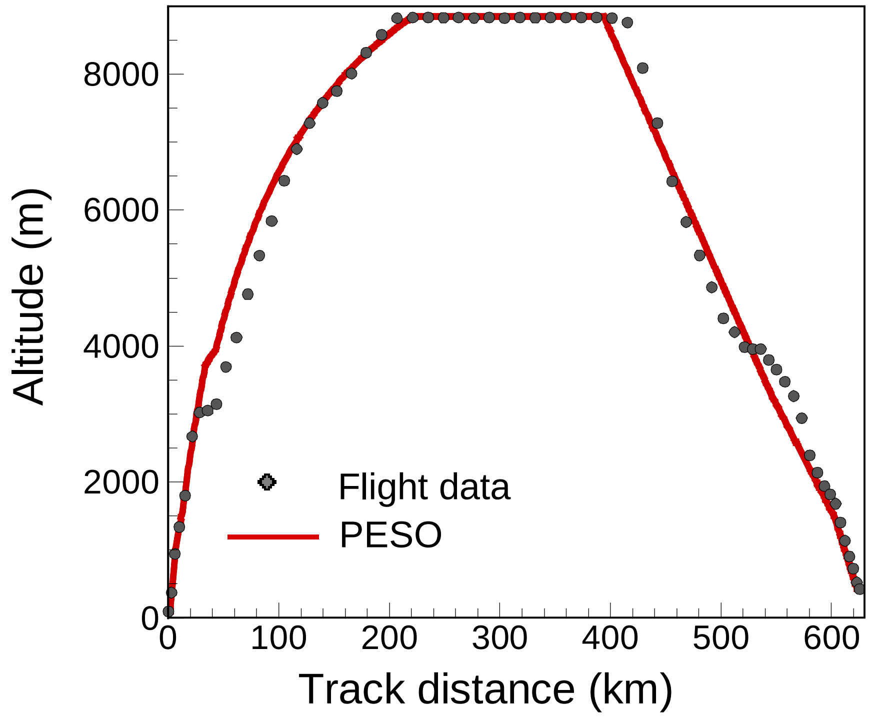


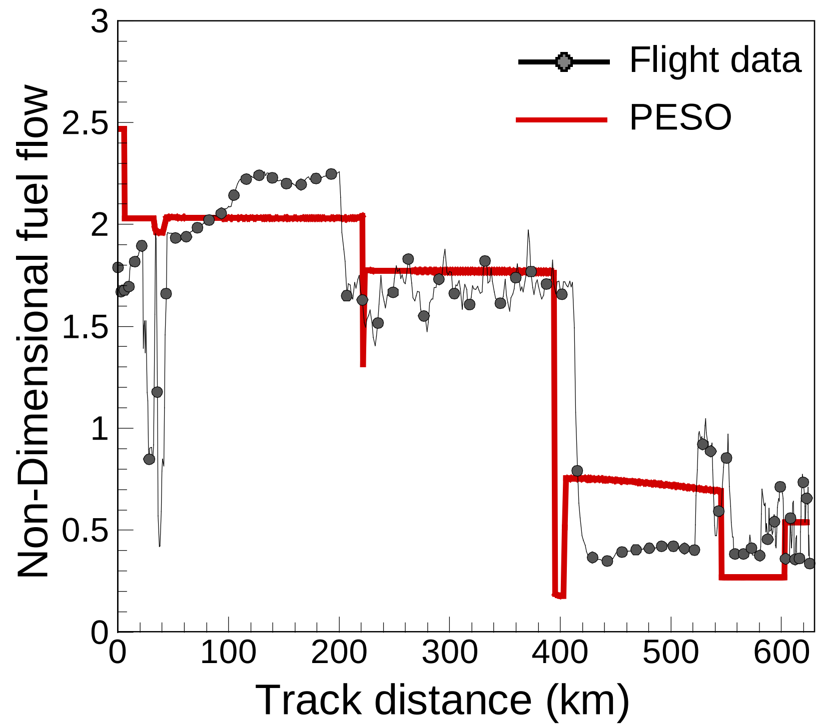


UNIVERSITY OF CAMBRIDGE

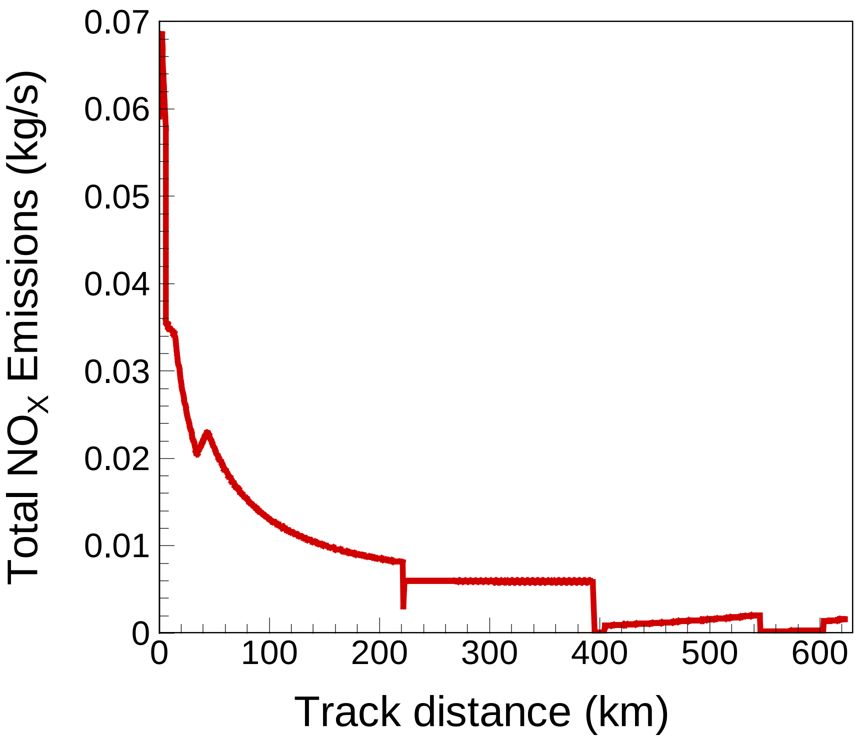
AIM

Applications: Full Mission





Applications: Full Mission



UNIVERSITY OF CAMBRIDGE

AIM

Conclusions

- New approach to the modelling of aircraft trajectories
- Methodology validated using flight data
- Results sensitive to the L/D ratio
- Within AIM: distributions of engine age and L/D to be used

- Future work
  - Modelling high lift devices/landing gear…
  - Modelling future technologies