Three-dimensional pseudo-unsteady viscous-inviscid interaction for finite wings in transonic flow

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AIAA SciTech 2024, January 8–12

Motivation

RANS

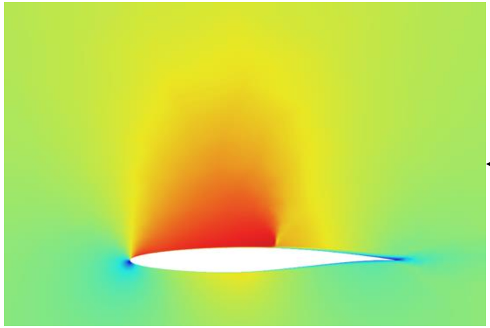
- High level of fidelity
- Viscous
- Shocks

Viscous inviscid interaction

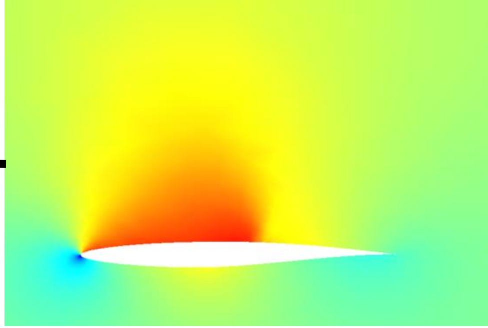
- Viscosity effects
- Corrected shock position
- Corrected shock strength

Inviscid flow

- No viscous effects
- Shock at 80% of chord
- Strong shock



← X50



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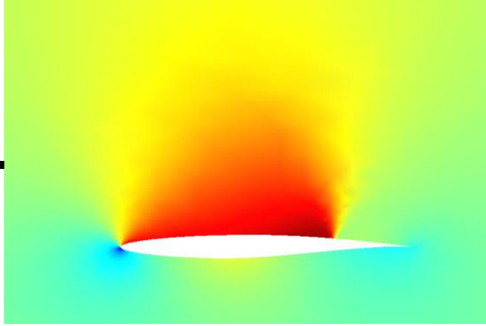
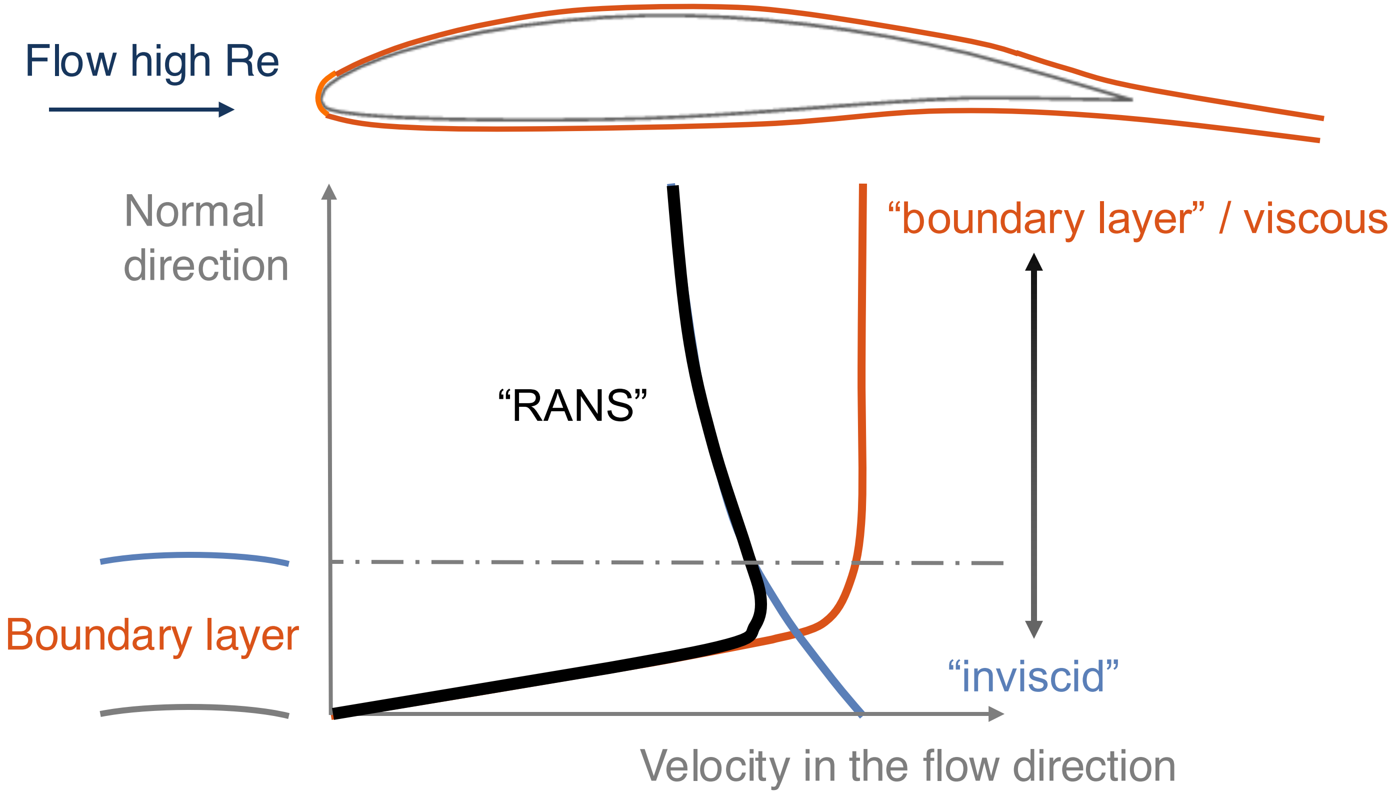
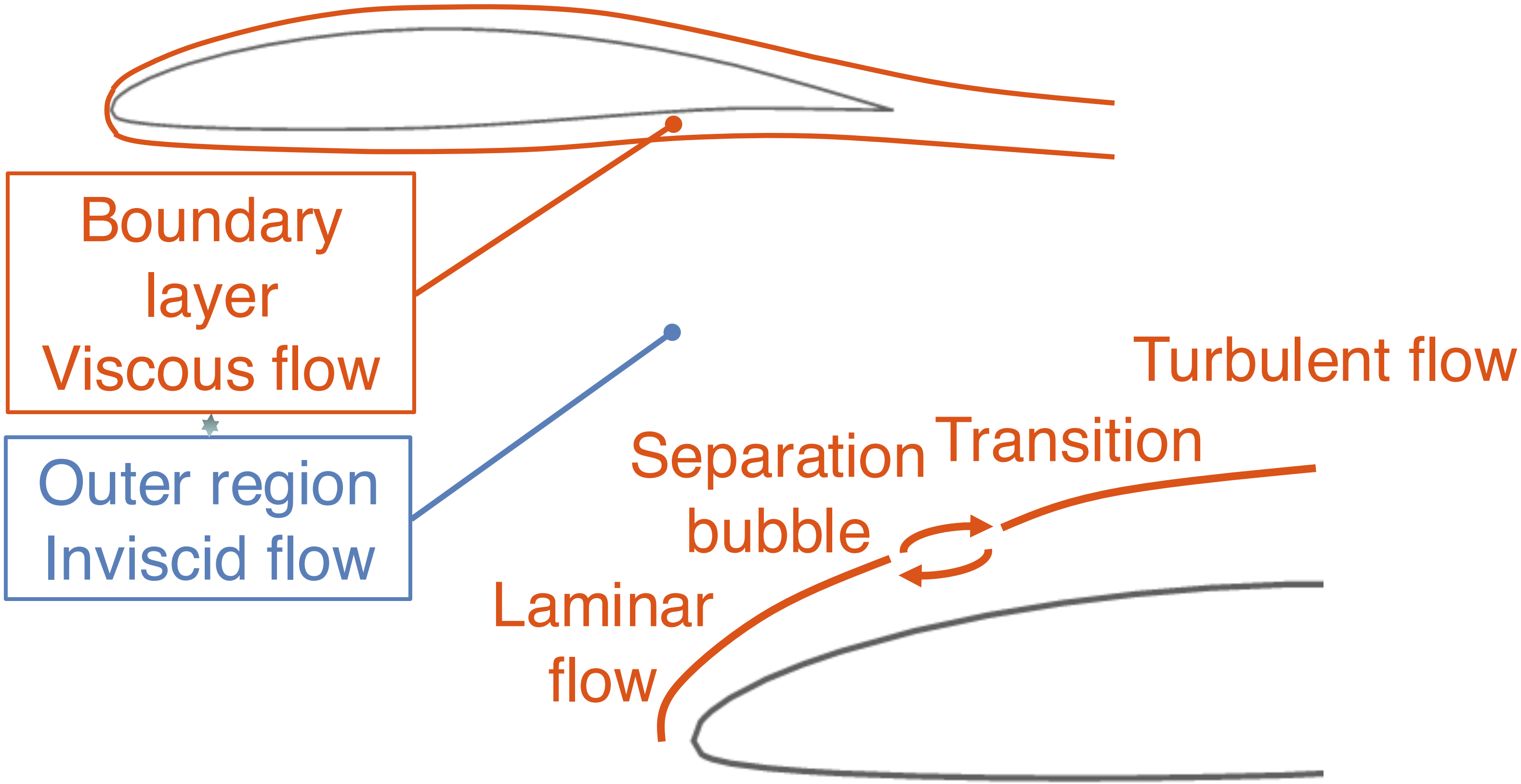


Mach number

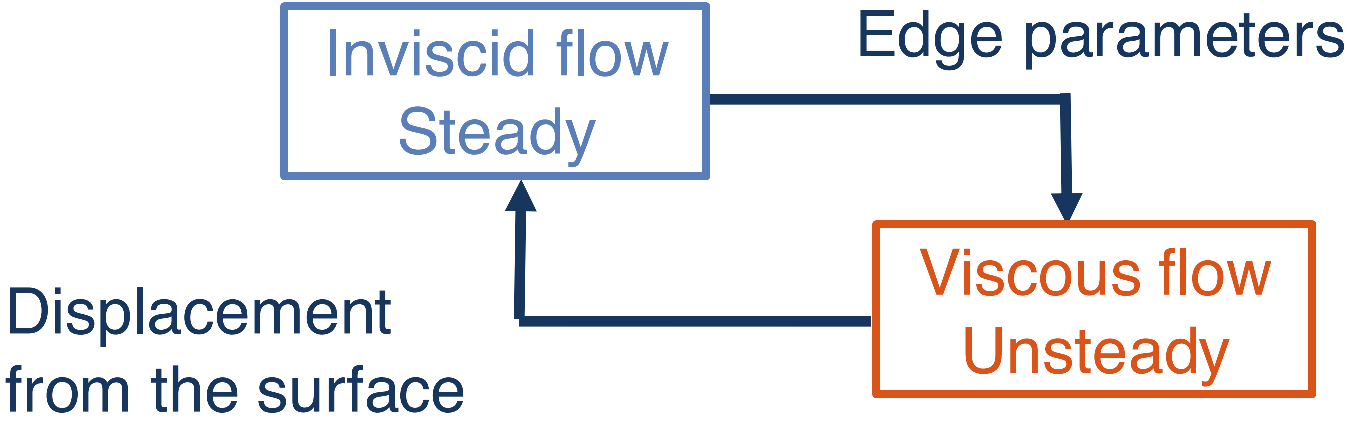
Viscous-inviscid interaction



Methodology



Methodology



- Steady full-potential Inviscid solver (DART)
- Pseudo-unsteady formulation of the boundary layer equations
- Computation of steady-states only
- This work uses the work of Drela (1986)

3D

Principle

- Inviscid flow computed on the 3D wing
- Boundary layer equations solved on sections
- Interpolation between regions

+ Very flexible
+ Complex geometries (unstructured mesh)

- Slower than litterature
- Limited for 3D effects

Coupling methods

Semi-inverse

- ✓ Solve issues
- x Slow

Quasi-simultaneous

- ✓ Fast
- ✓ Modular
- x Slower than simultaneous

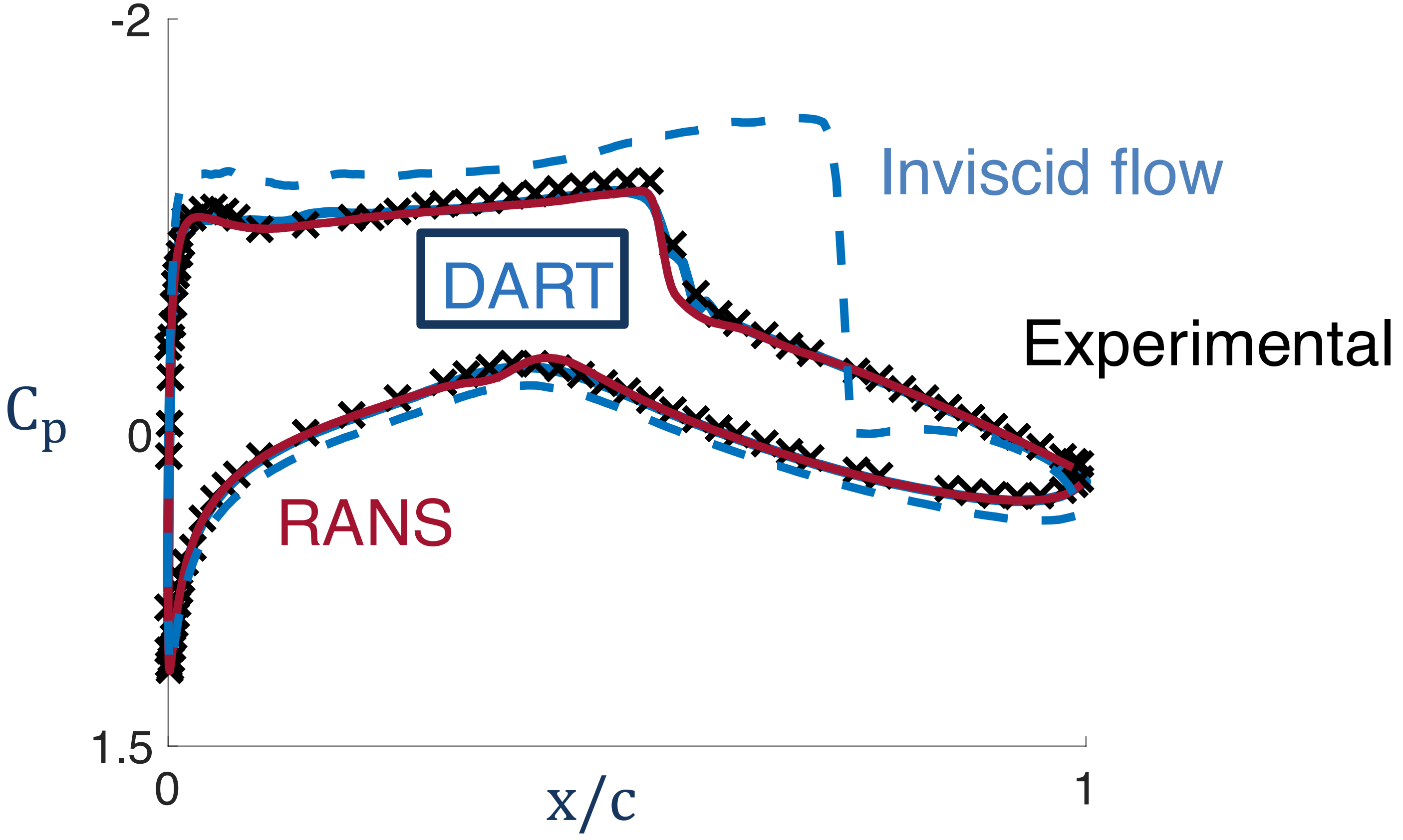
Fully-simultaneous

- ✓ Fastest
- x Flexibility
- x Robustness

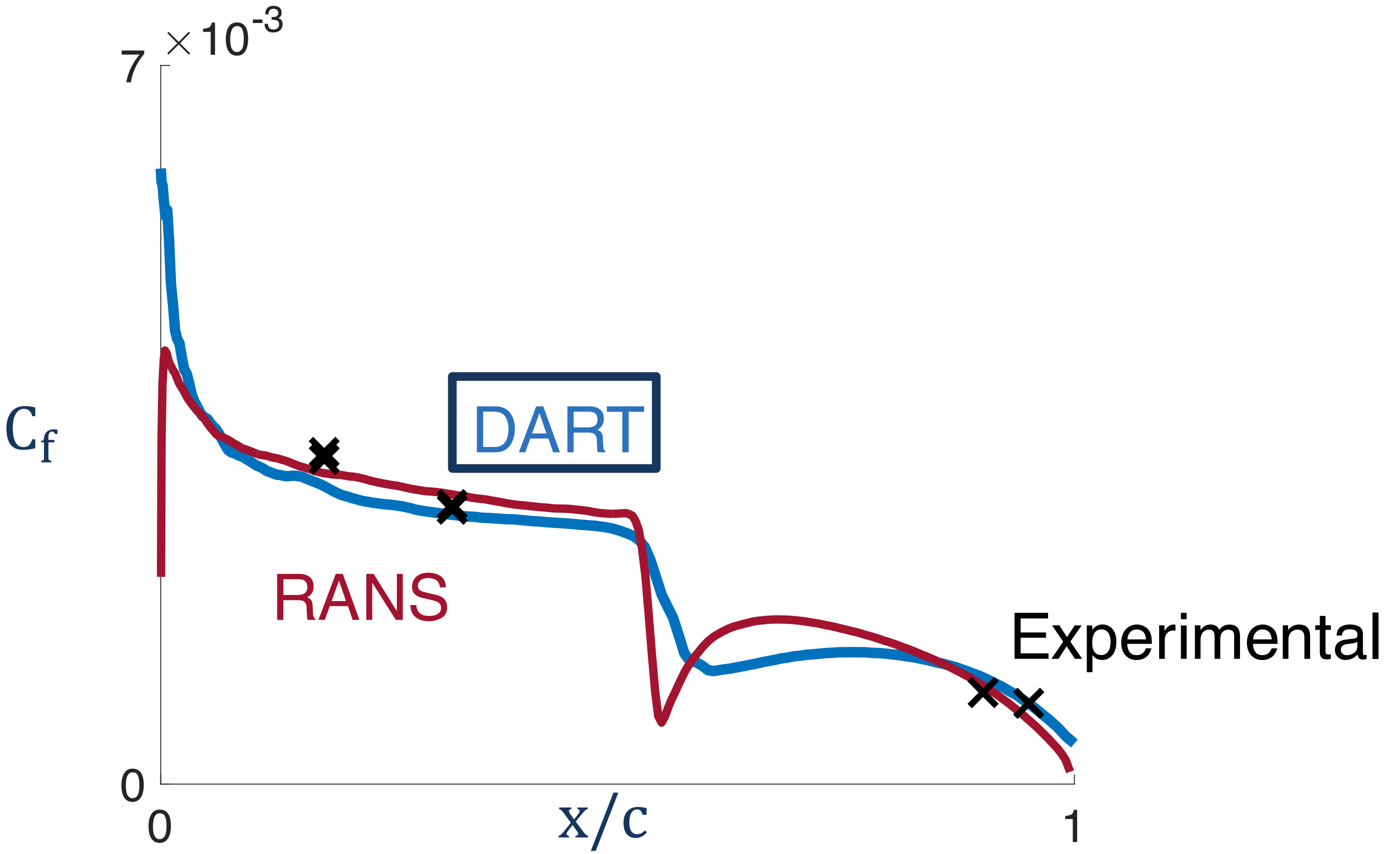
RAE2822 – 2D

Angle of attack	$+2.31°$
Mach number	0.73
Reynolds number	6.5×10^5

Pressure coefficient

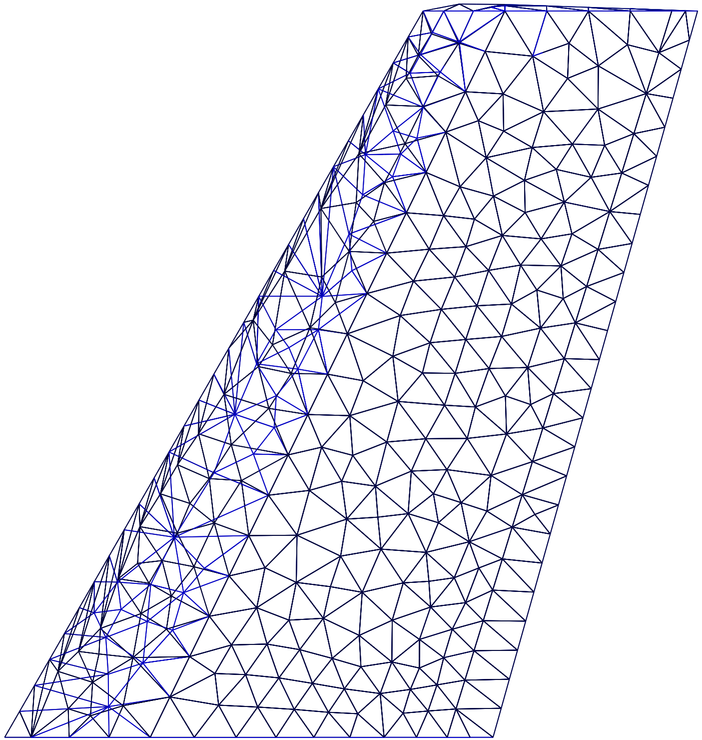


Friction coefficient – suction side



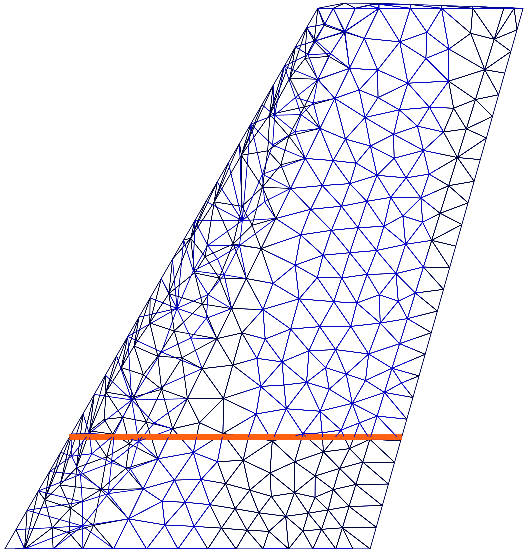
Onera M6 – 3D

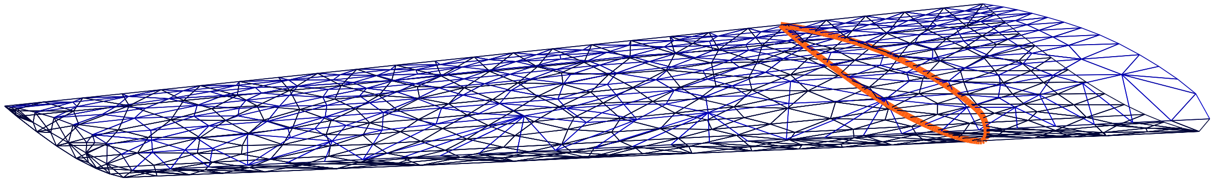
Angle of attack	$+3°$
Mach number	0.84
Reynolds number	11.72 mil



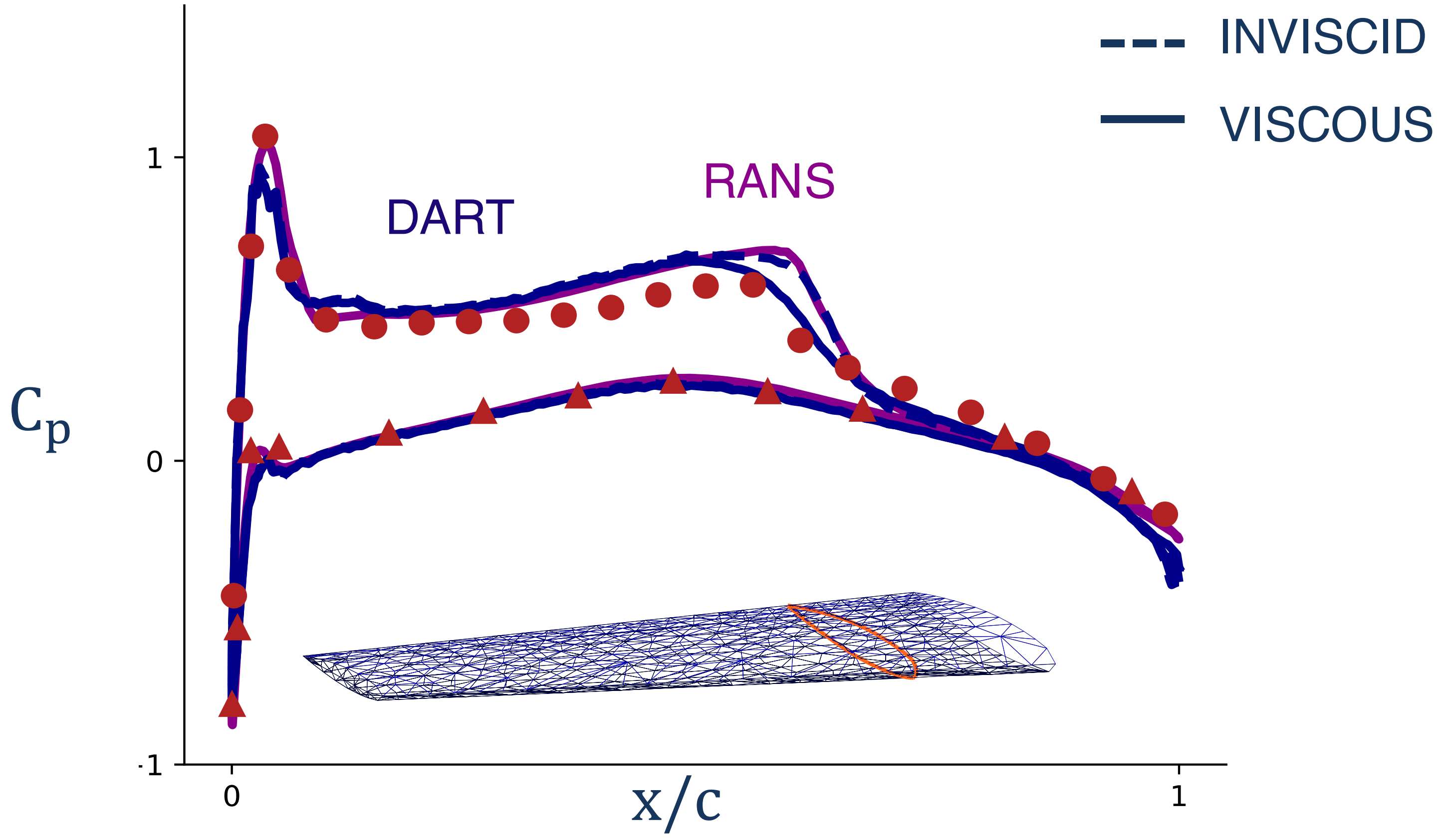
Onera M6 – 3D

Inboard section; 20 % of the span

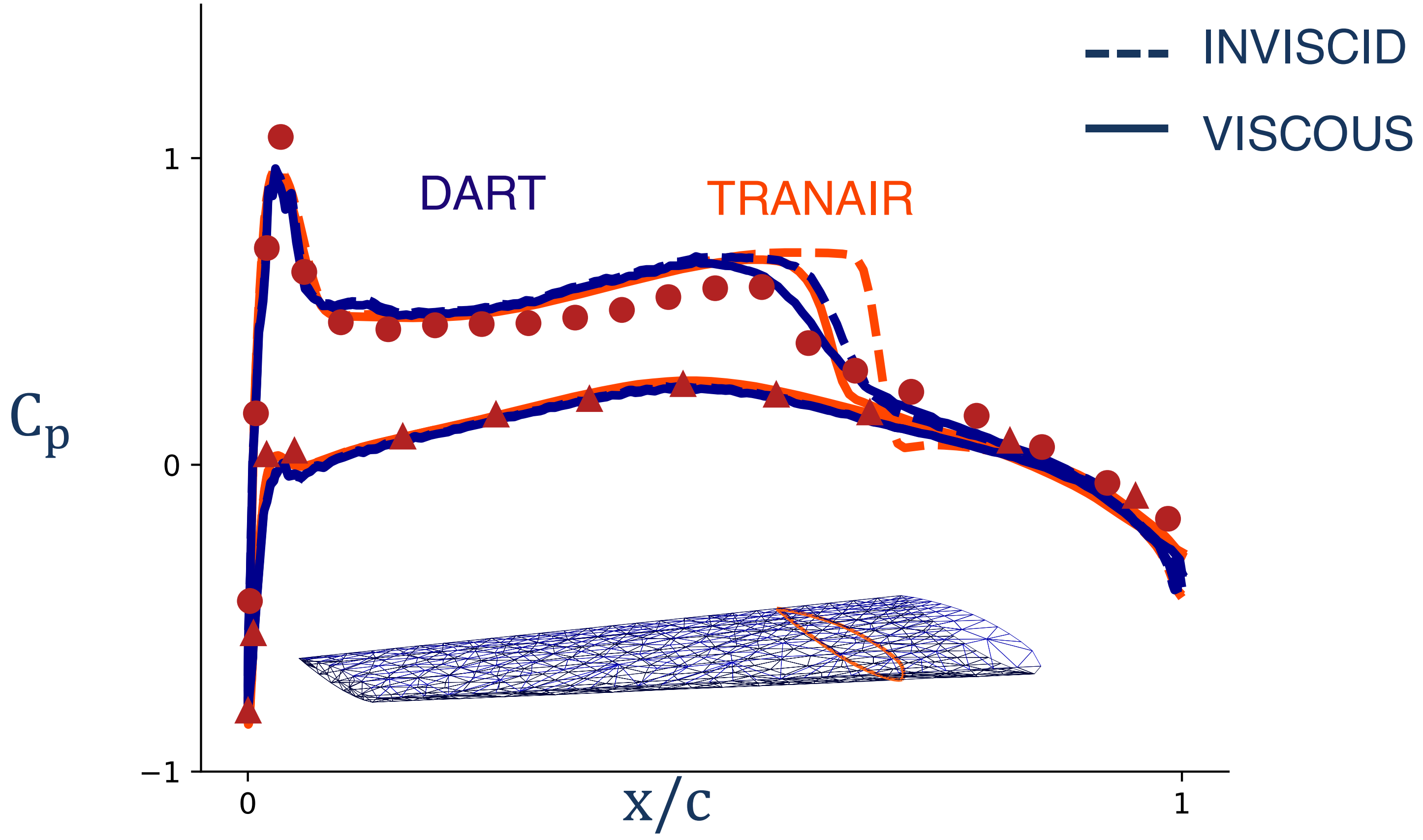




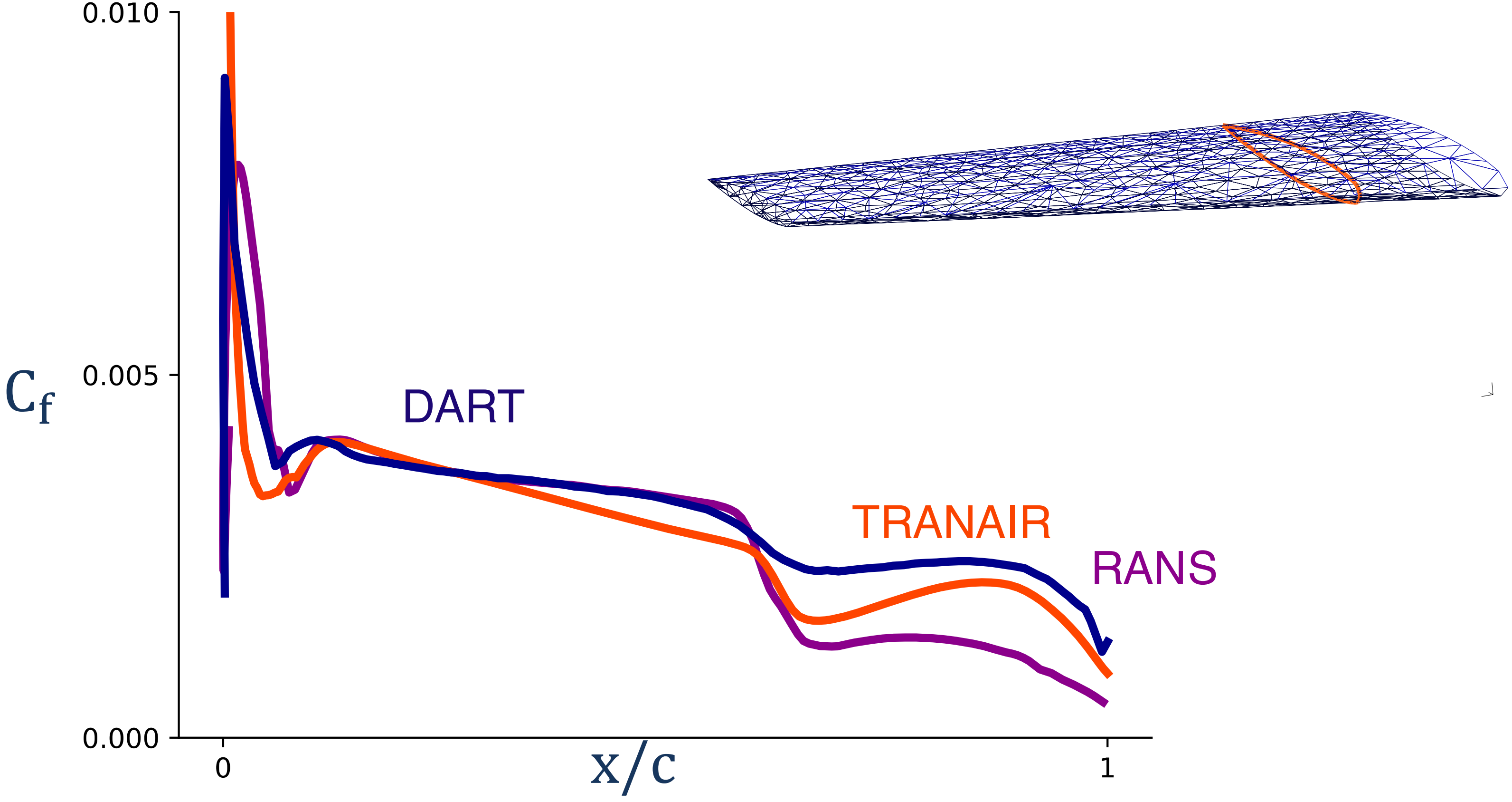
Pressure coefficient



Pressure coefficient

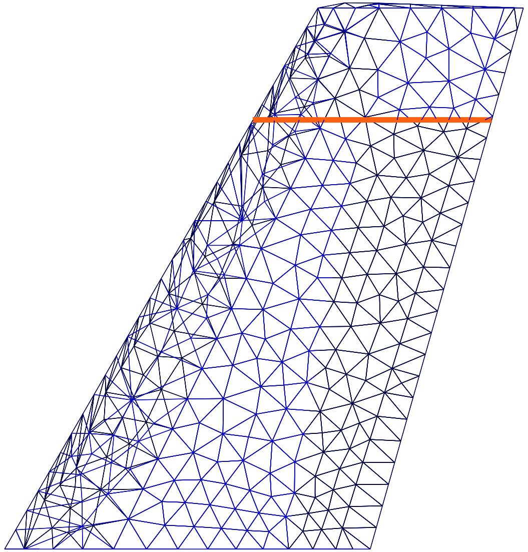


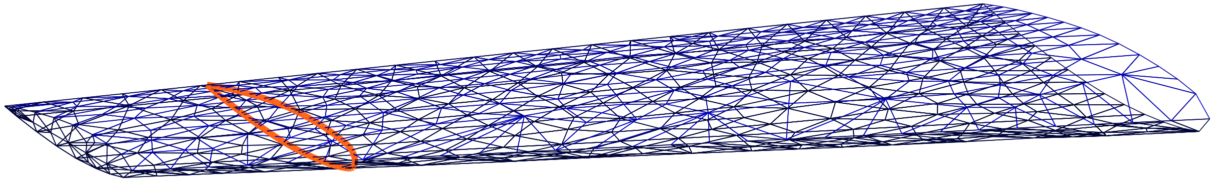
Friction coefficient



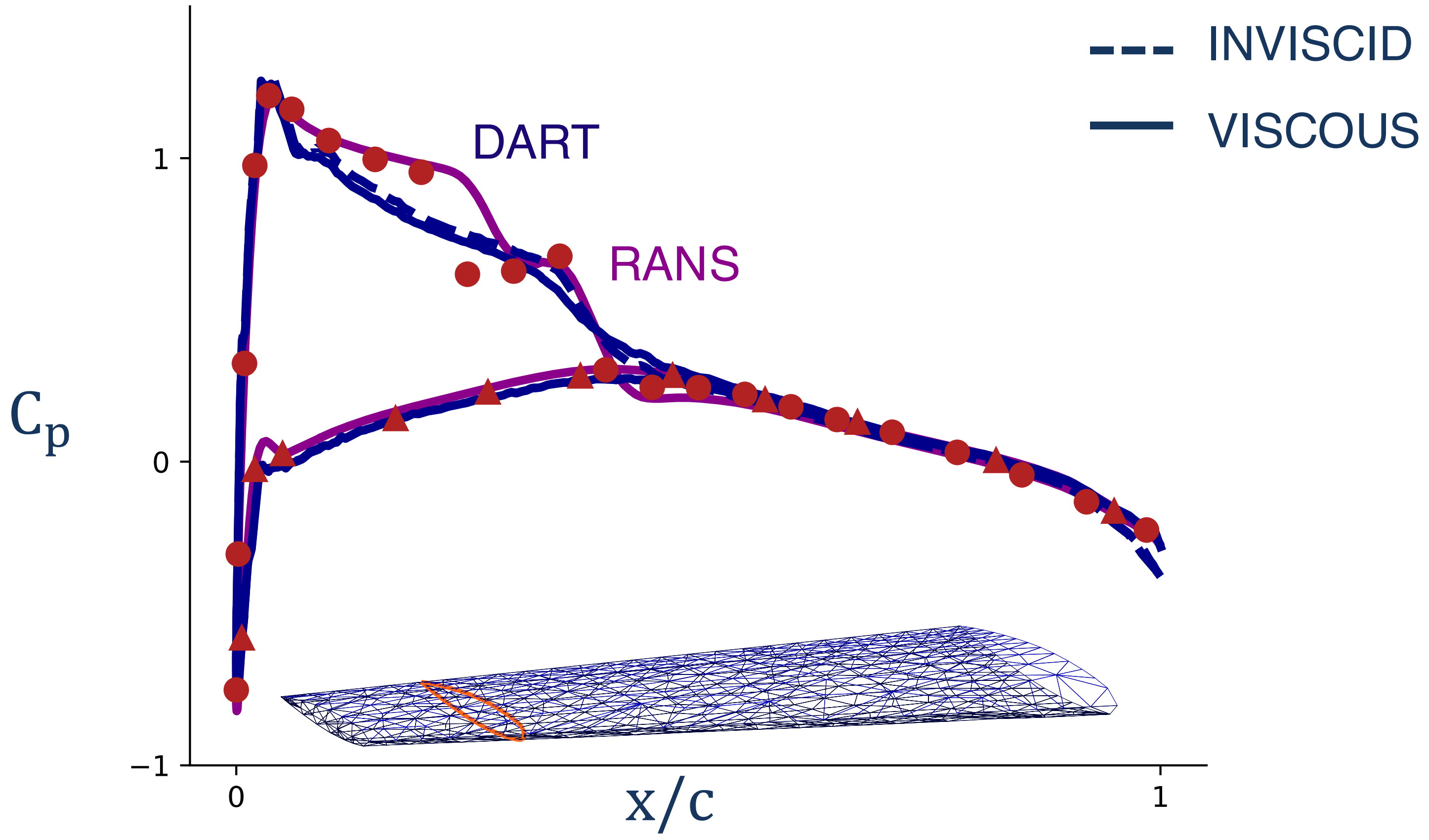
Onera M6 – 3D

Outboard section; 80 % of the span

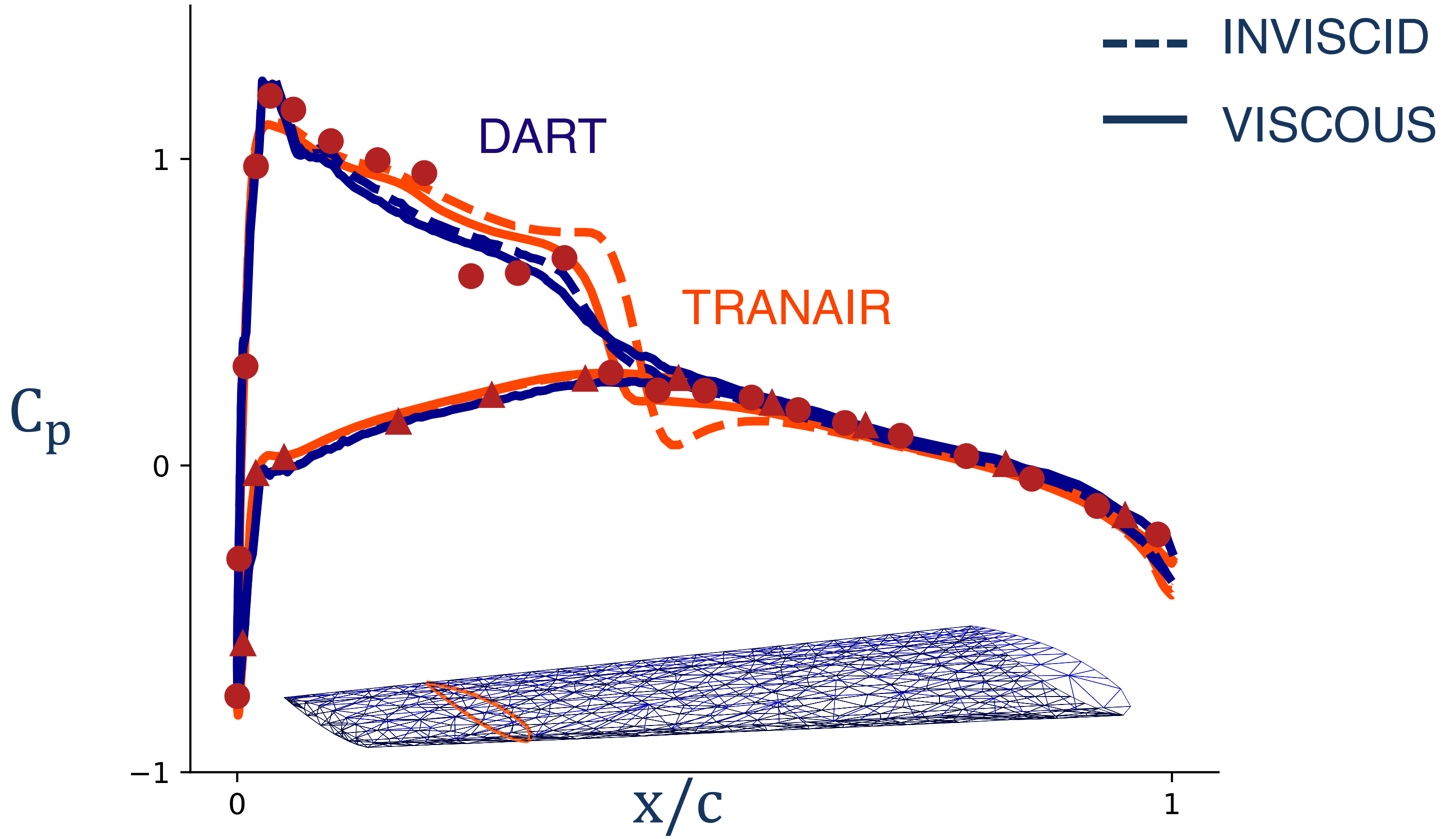




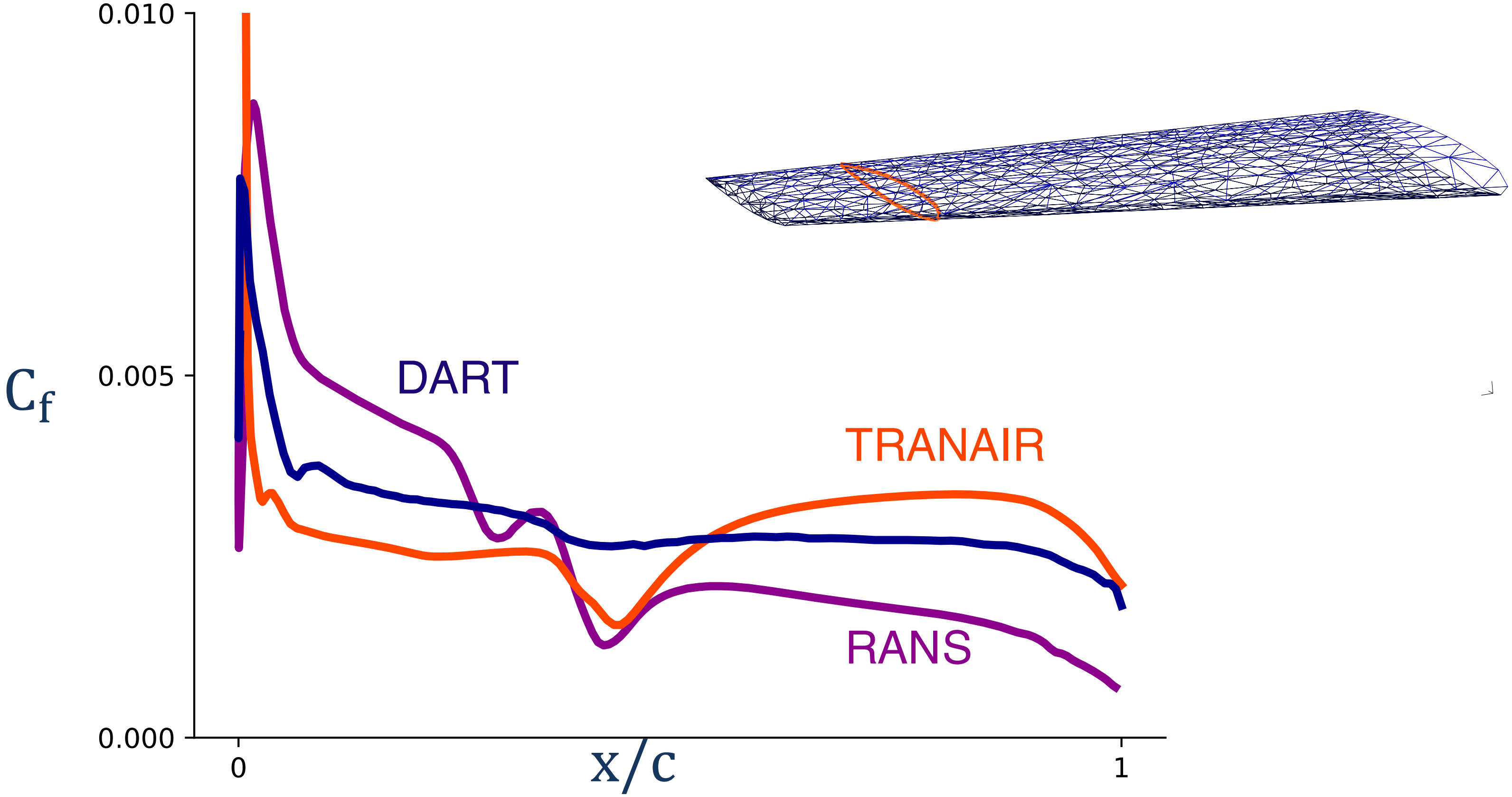
Pressure coefficient



Pressure coefficient



Friction coefficient



Aerodynamic coefficients

Solver	CL	CD	CL INV	CD INV
DART	0.283	0.0160	0.294 (+3%)	0.0109 (-30%)
TRANAIR	0.255	0.0161	0.288 (+13%)	0.0111 (-31%)
RANS	0.286	0.0130	-	-

Solver	Number of cells	Total time
DART	700,000	13 min
TRANAIR	500,000	8 min
RANS	1,500,000	hours

Conclusion

- Developed a viscous-inviscid interaction scheme with a full-potential solver
- Pseudo-unsteady boundary layer equation
- Novel strip-based coupling approach
- Demonstrated on 2D and 3D test cases
- Good compromise between RANS and inviscid flow