

FUN3D Airload Predictions for the Full-Scale UH-60A Airloads Rotor in a Wind Tunnel

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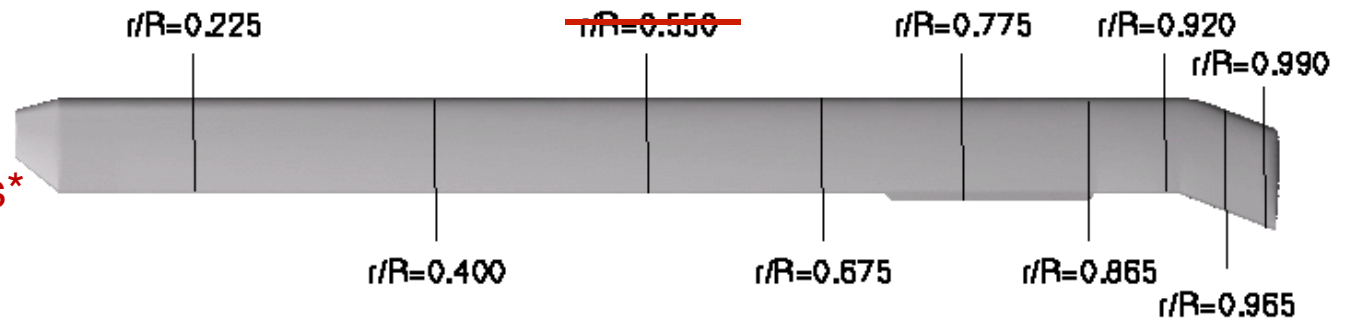
Motivation and Methodology

- UH60A Airloads Flight Test CFD/CSD correlations
 - Recent code-to-code comparisons show remarkably similar results from CFD: OVERFLOW / FUN3D / HELIOS
 - Much less difference between various computed results than between computed results and flight data
- UH60A Airloads Wing Tunnel Test CFD/CSD correlations
 - Simplified geometry (no tail rotor/propulsion)
 - Additional measurements provide new insights
- Start with Speed Sweep data points that have a similar condition to C8534
 - C8534: $\mu = 0.371$ $C_T/\sigma = 0.081$ (roll/pitch moment trim 6042/-4169 in-lb.)
 - R52 P40: $\mu = 0.37$ $C_T/\sigma = 0.0907$ (roll/pitch moment trim 2834/-2565 in-lb.)

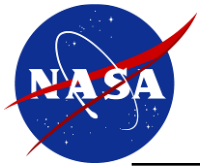


UH60A Airloads Wind Tunnel Test

- Joint NASA/Army NFAC Test
- Same rotor blades as flight
- Test conditions:
 - 1-g level flight speed sweeps
 - Parametric sweeps
 - Slowed rotor
- Comprehensive test measurements including:
 - Sectional airloads (pressures) at 8 radial locations
 - Balance loads*
 - Control settings*
 - Blade root motions*
 - Blade deflection*
 - Wake PIV*
 - Structural loads



* Measurement not available from flight test



Outline

- CFD/CSD methodology & models
- Study effects of aerodynamic modeling
 - Isolated rotor (5 test points)
 - LRTA body and hub (3 test points)
 - LRTA body/hub + trim tab deflections (1 test point)
 - Wind tunnel walls (3 test points)
- Comparison of FUN3D/CAMRADII loose-coupling results with UH60A Airloads NFAC speed sweep data
 - Rotor performance
 - Sectional airloads/pressure distributions
- Concluding Remarks



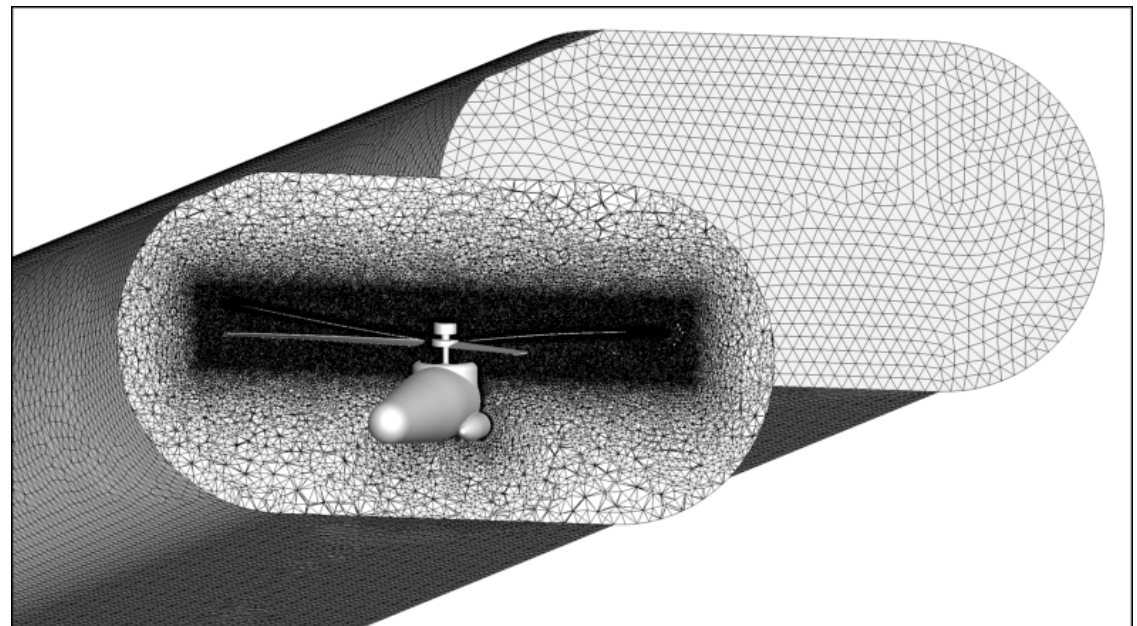
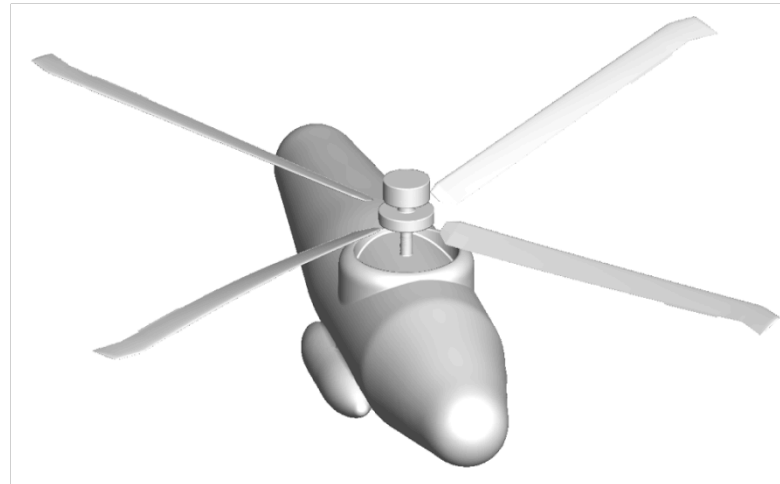
FUN3D/CAMRADII Model

- FUN3D model (baseline from flight test computations)
 - Isolated rotor grid with off-body spacing 10% tip chord
 - Mixed-element overset mesh with 15 million nodes
 - 1 deg. azimuth per timestep/Spalart-Allmaras turb. model
 - Free-air computation – corrected shaft angle
- CAMRADII model (Hyeonsoo Yeo)
 - Same structural model as used for flight test
 - Trim to match experimental thrust, pitch/roll moments
 - Some changes based on Ethan's recommendation
 - Increased number of radial aero. panels from 21 to 100
 - Increased azimuthal resolution from 24 to 360
- Loose-coupling approach for CFD/CSD
 - Thrust match between CAMRADII and CFD less than 1%
 - Pitch and roll moments match 2-3%



FUN3D LRTA & Tunnel CFD Models

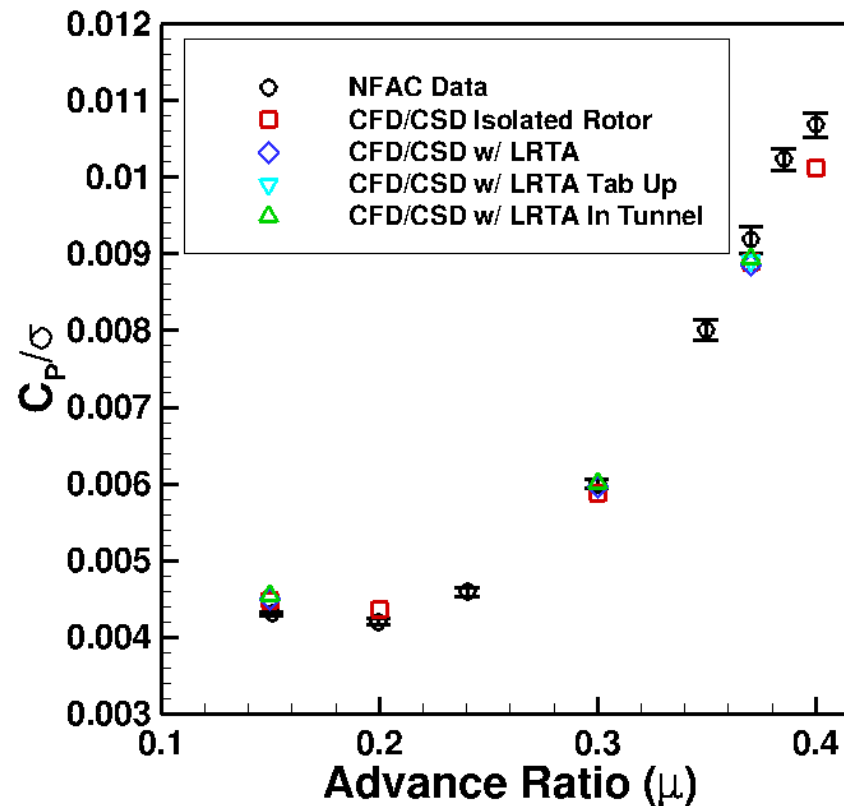
- Free-air rotor and LRTA/hub
 - Same blade grids/off-body spacing
 - 18 million nodes
 - Same numerical parameters/models
 - Corrected shaft angle
- In Tunnel rotor and LRTAhub
 - Same blade grids/off-body spacing
 - LRTA/hub surface grids
 - Simplified tunnel(inviscid)
 - Same numerical parameters/models
 - Geometric shaft angle



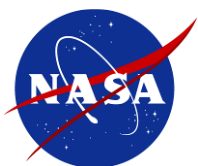


1-g Level Flight Speed Sweep Results

Solidity-Weighted Rotor Balance Power

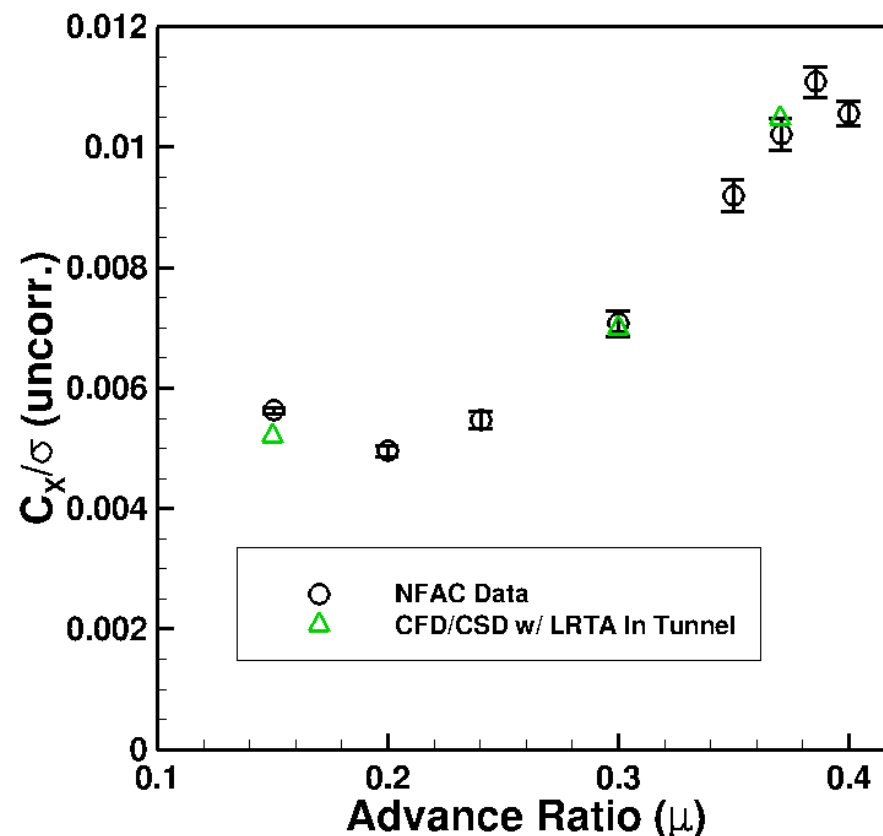
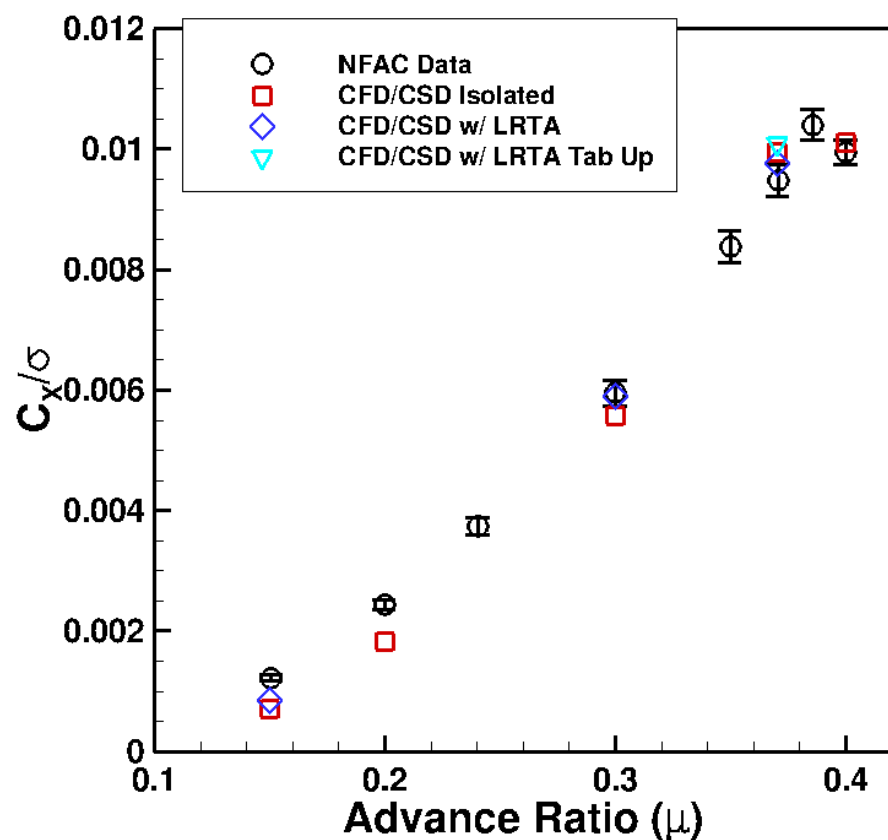


- Increase in forward speed (advance ratio) at constant rotor solidity-weighted lift coefficient $C_L/\sigma = 0.902$
- Rotor power (torque) predictions trend similar to experiment and OVERFLOW results with small sensitivity to LRTA and wind tunnel modeling

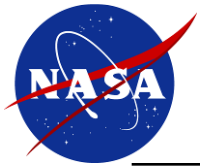


1-g Level Flight Speed Sweep Results

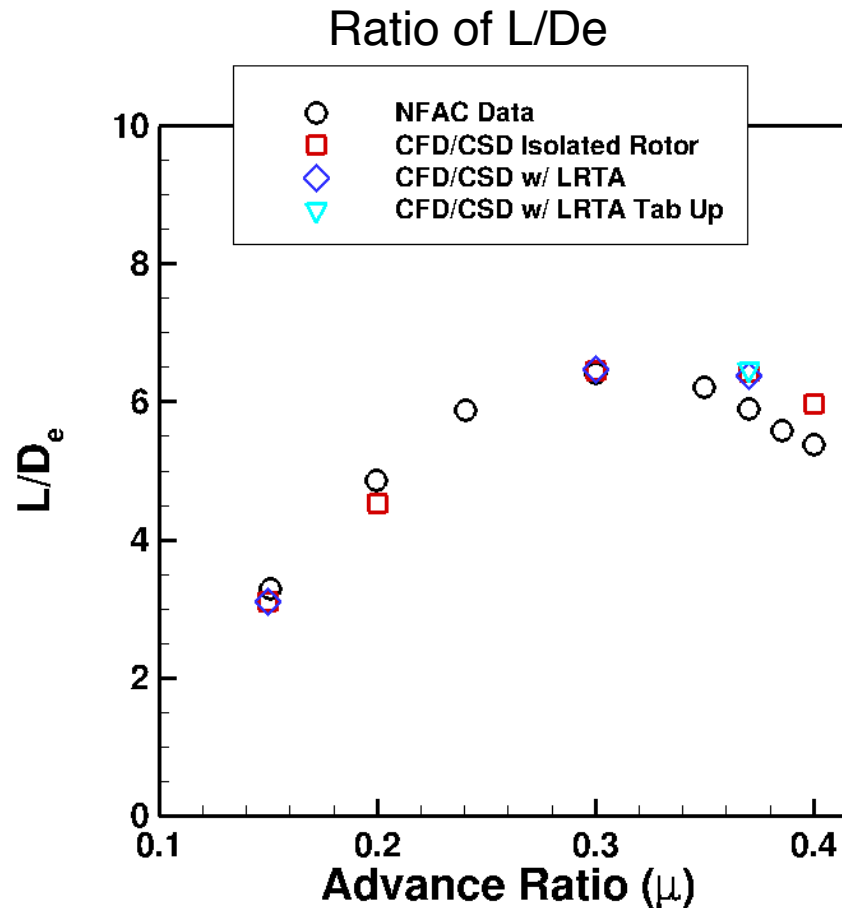
Solidity-Weighted Rotor Balance Propulsive Force



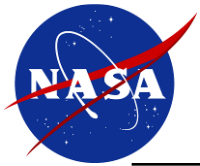
- Rotor propulsive force predictions trend similar to experiment and OVERFLOW results with some sensitivity to LRTA modeling
- Small sensitivity to wind tunnel modeling



1-g Level Flight Speed Sweep Results



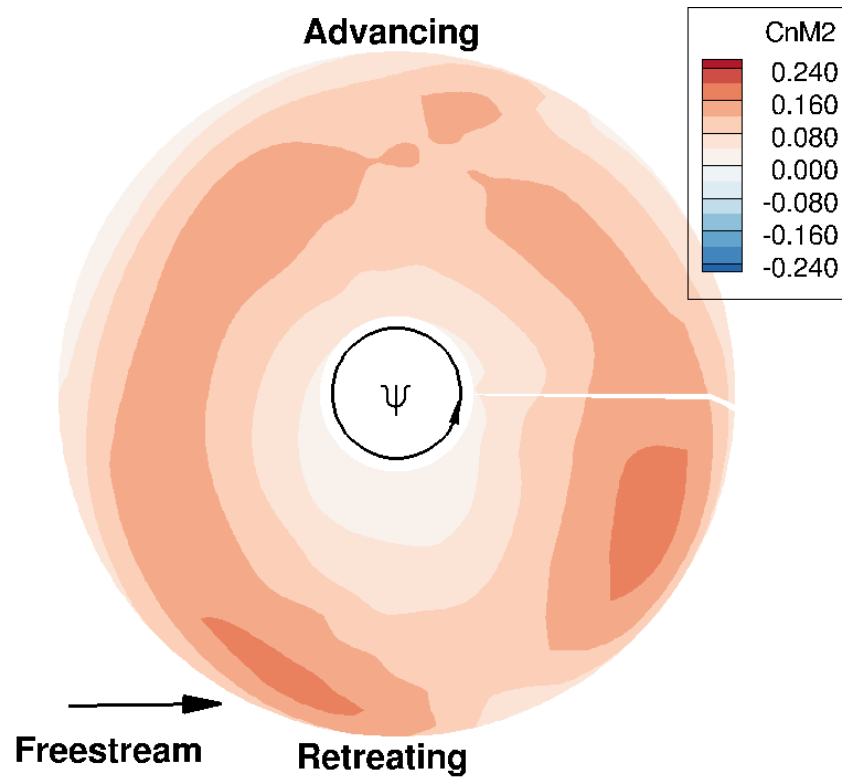
– Predictions trend similar to experiment with small sensitivity to LRTA and wind tunnel modeling



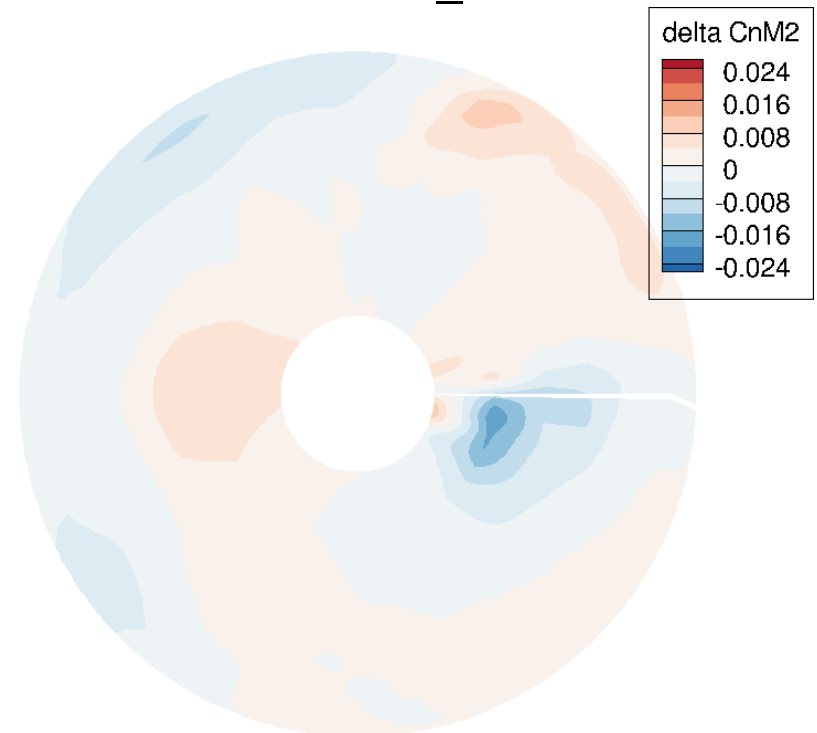
Sectional $C_n M^2$ Polar Plots $\mu=0.15$

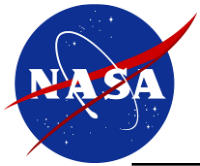
Isolated Rotor
contour scale ± 0.24

Advancing



Delta $C_n M^2$ due to LRTA
contour scale ± 0.024

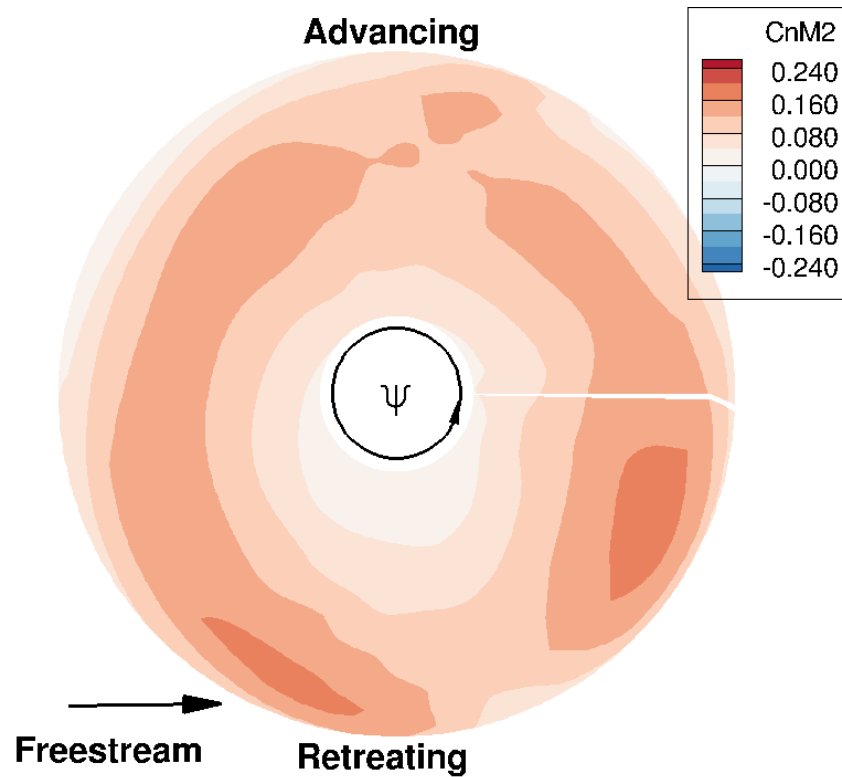




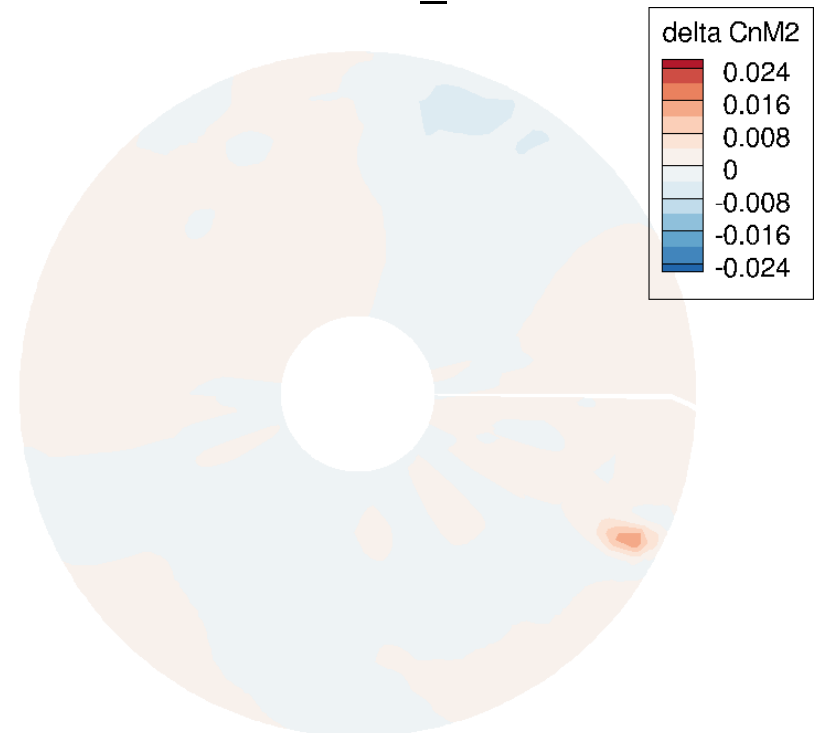
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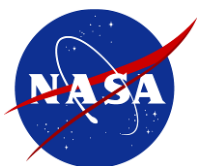
Isolated Rotor
contour scale ± 0.24

Advancing



Delta $C_n M^2$ due to Tunnel Walls
contour scale ± 0.024

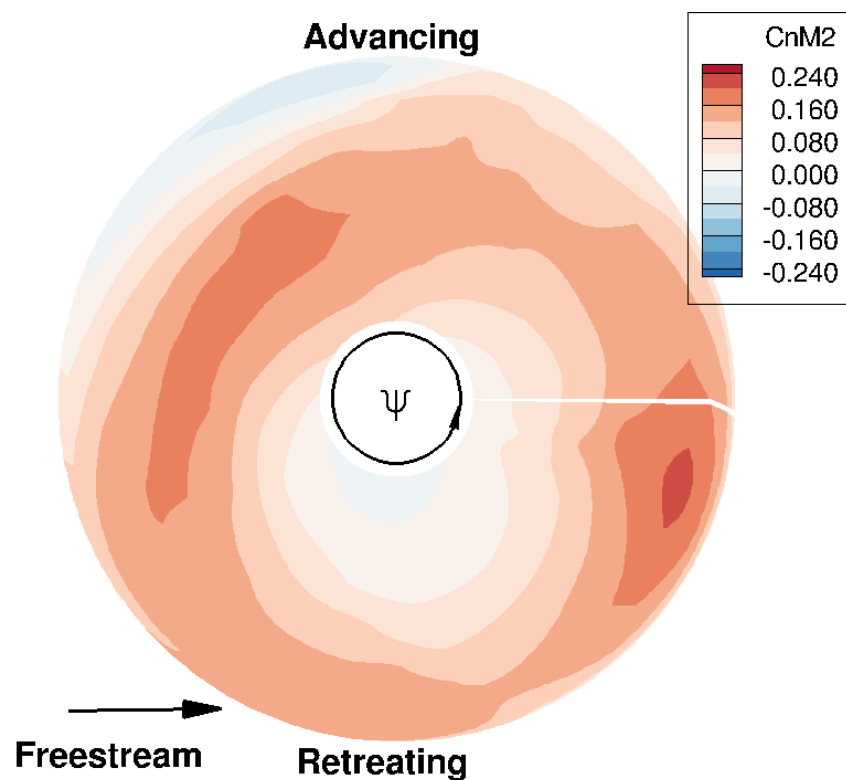




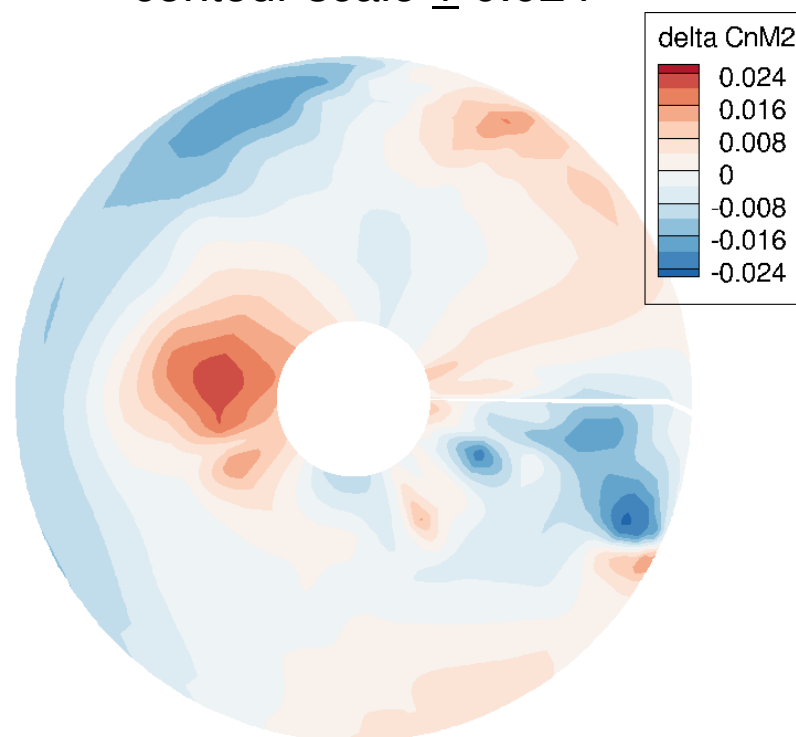
Sectional $C_n M^2$ Polar Plots $\mu=0.30$

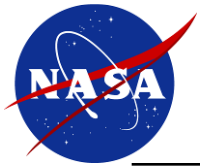
Isolated Rotor
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Advancing



Delta $C_n M^2$ due to LRTA
contour scale ± 0.024

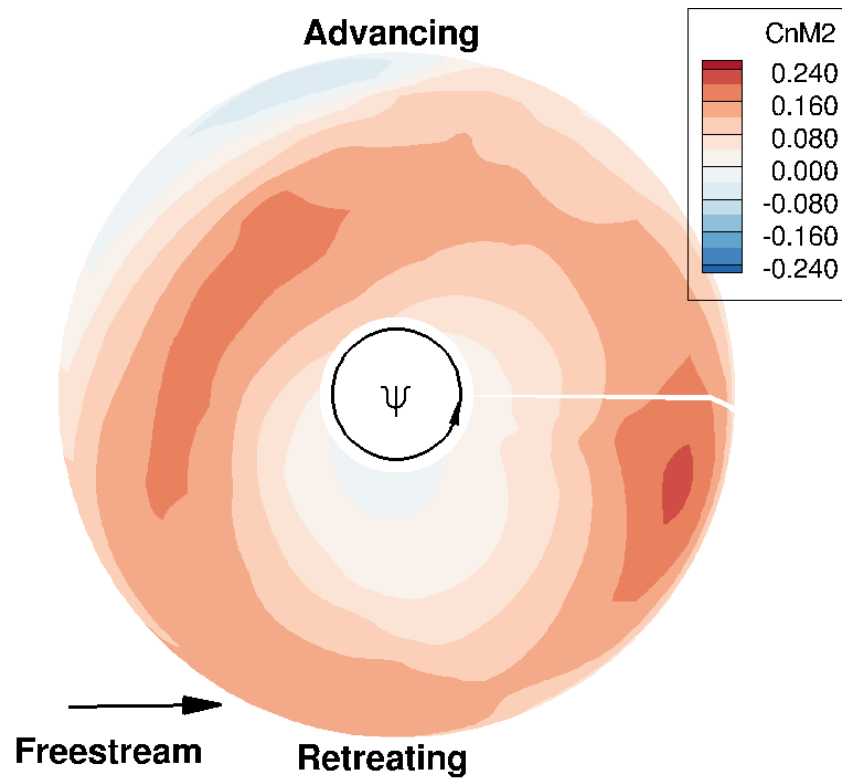




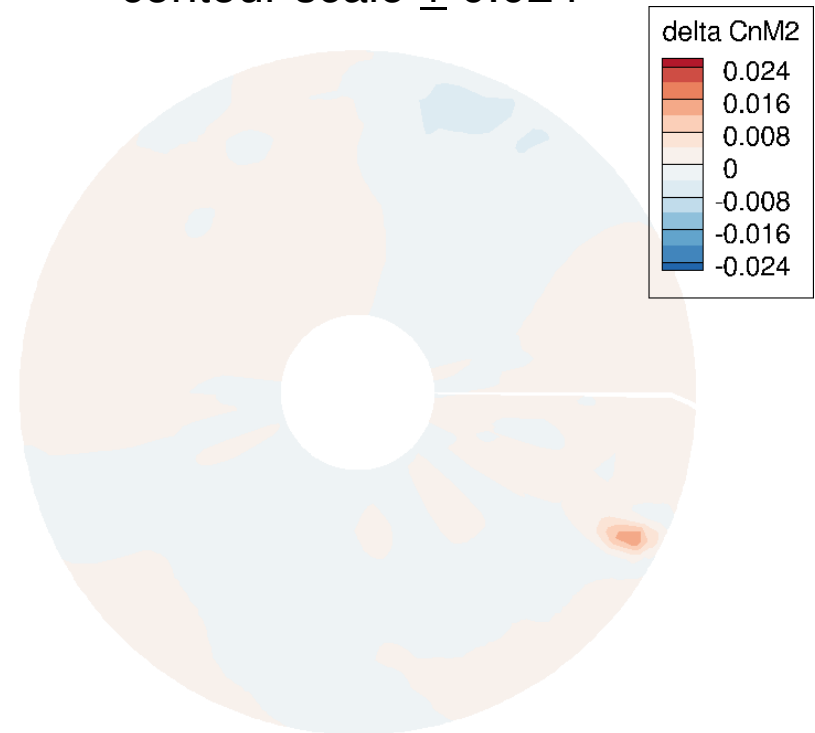
Sectional $C_n M^2$ Polar Plots $\mu=0.30$

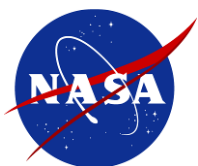
Isolated Rotor
contour scale ± 0.24

Advancing



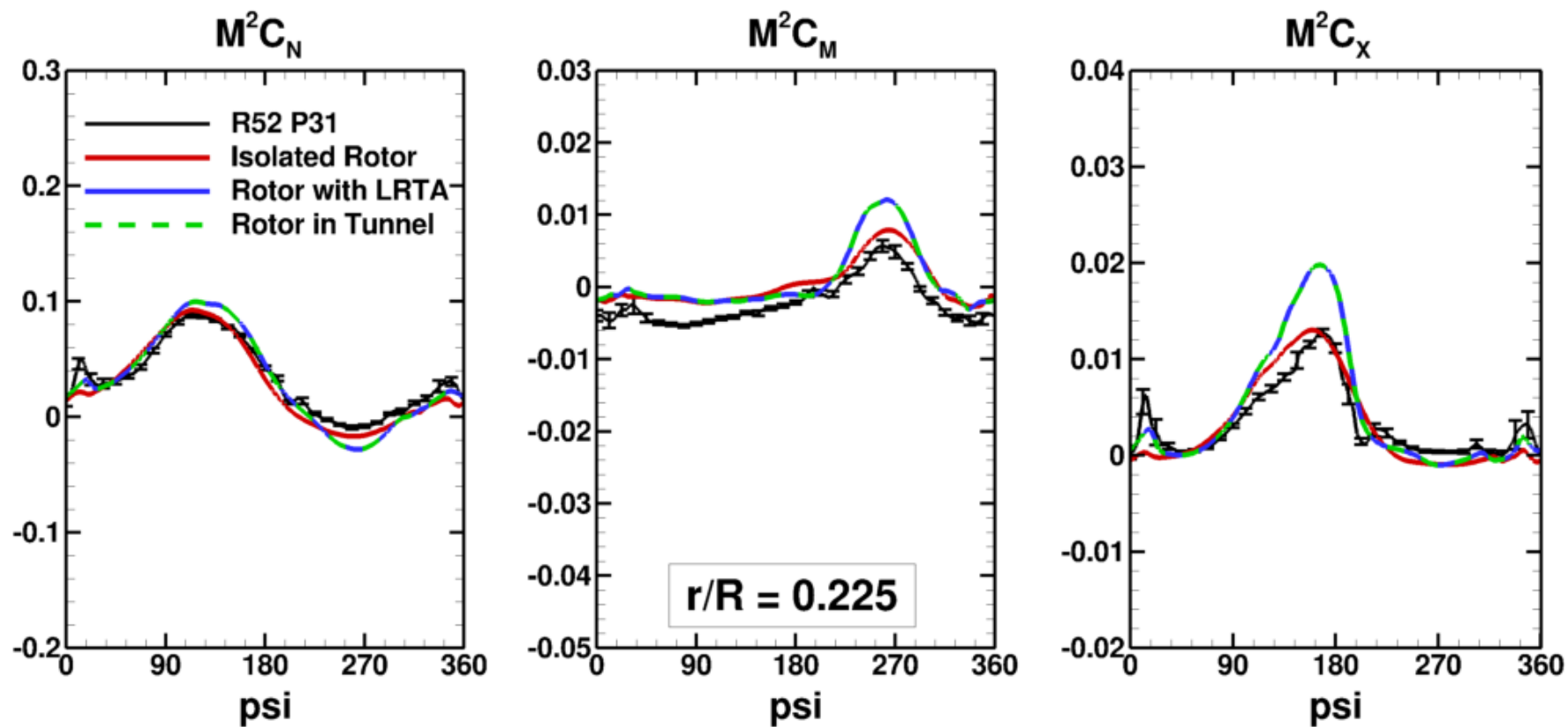
Delta $C_n M^2$ due to Tunnel Walls
contour scale ± 0.024

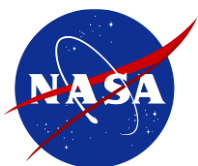




Sectional Loads $\mu=0.30$

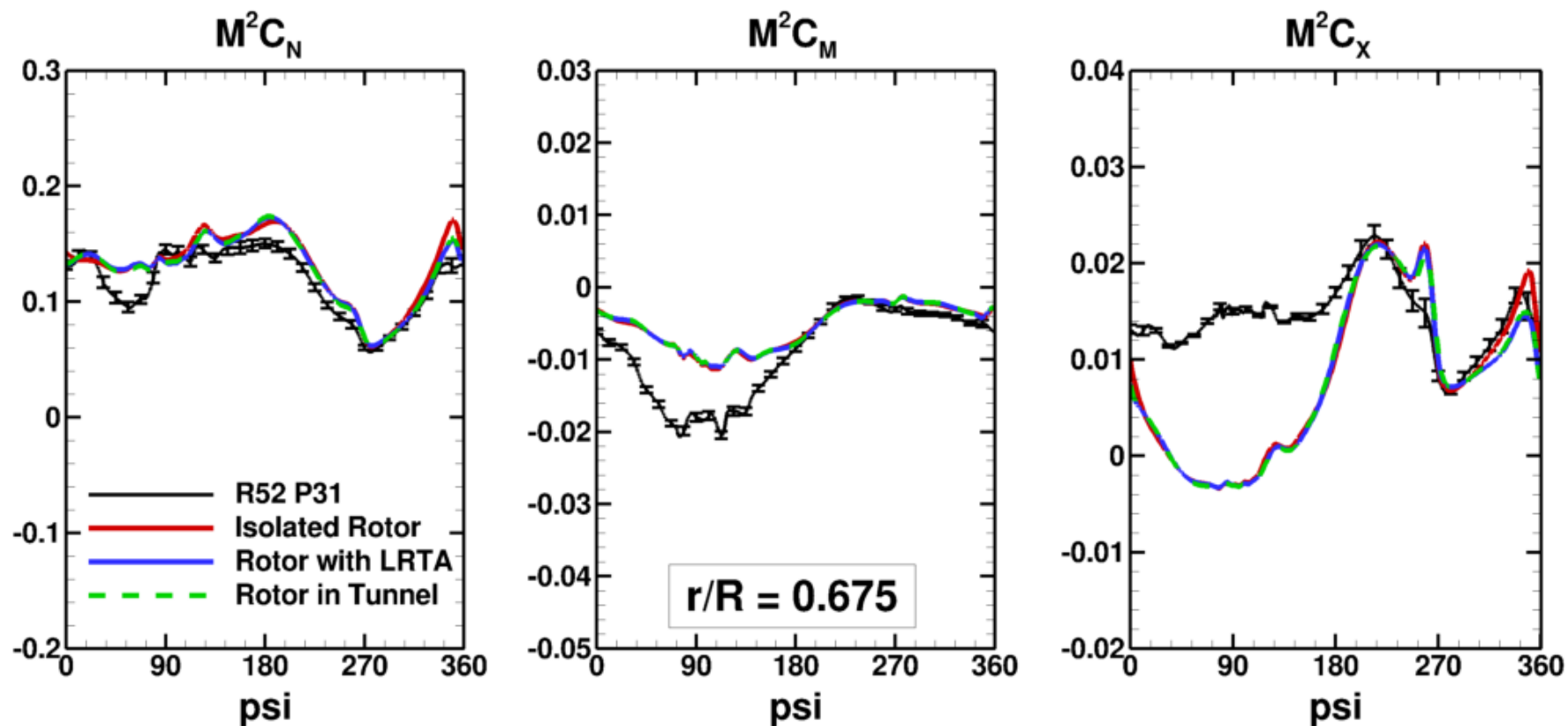
Effect of configuration

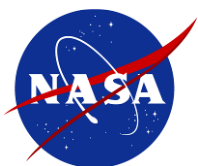




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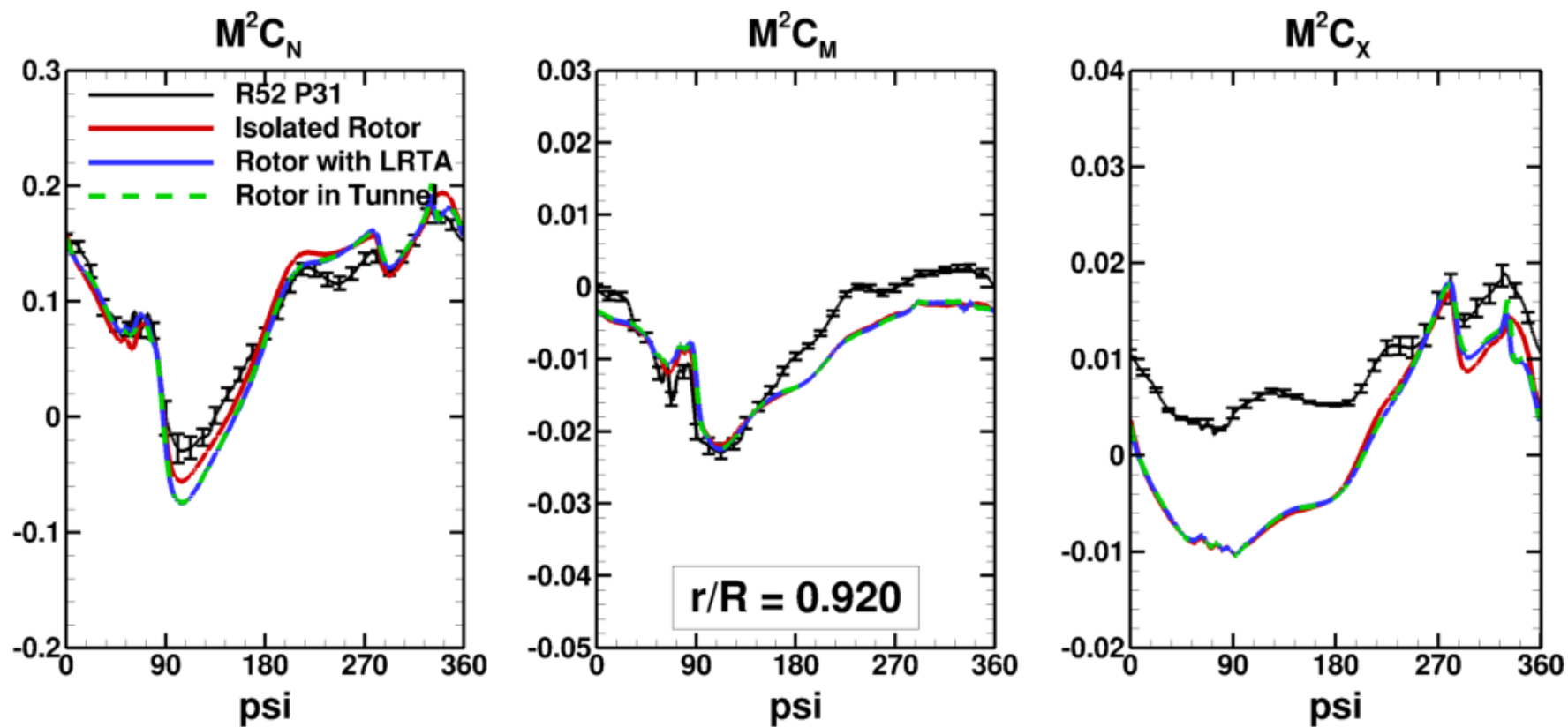
Effect of configuration

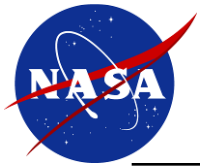




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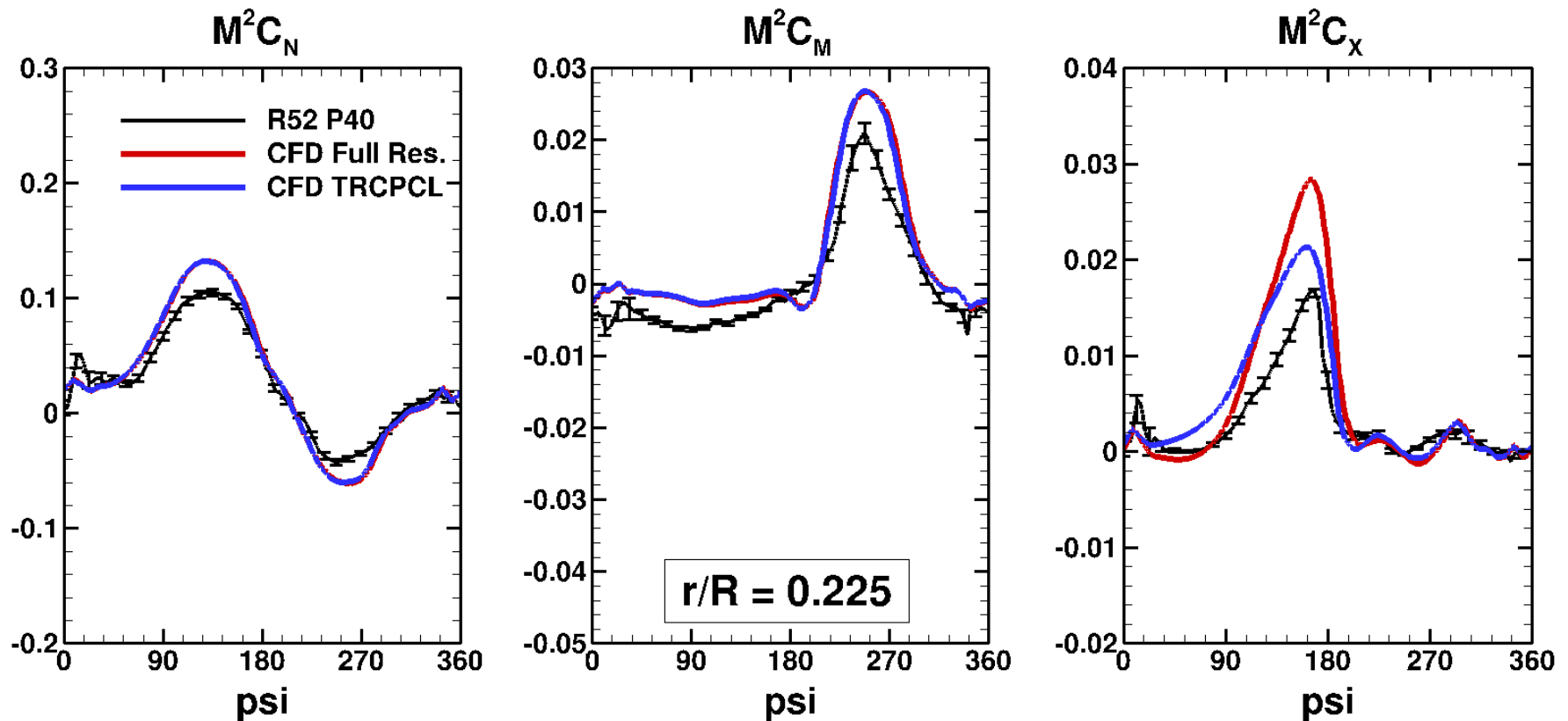
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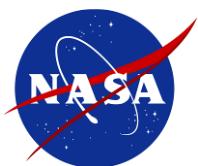




Sectional Loads $\mu=0.37$

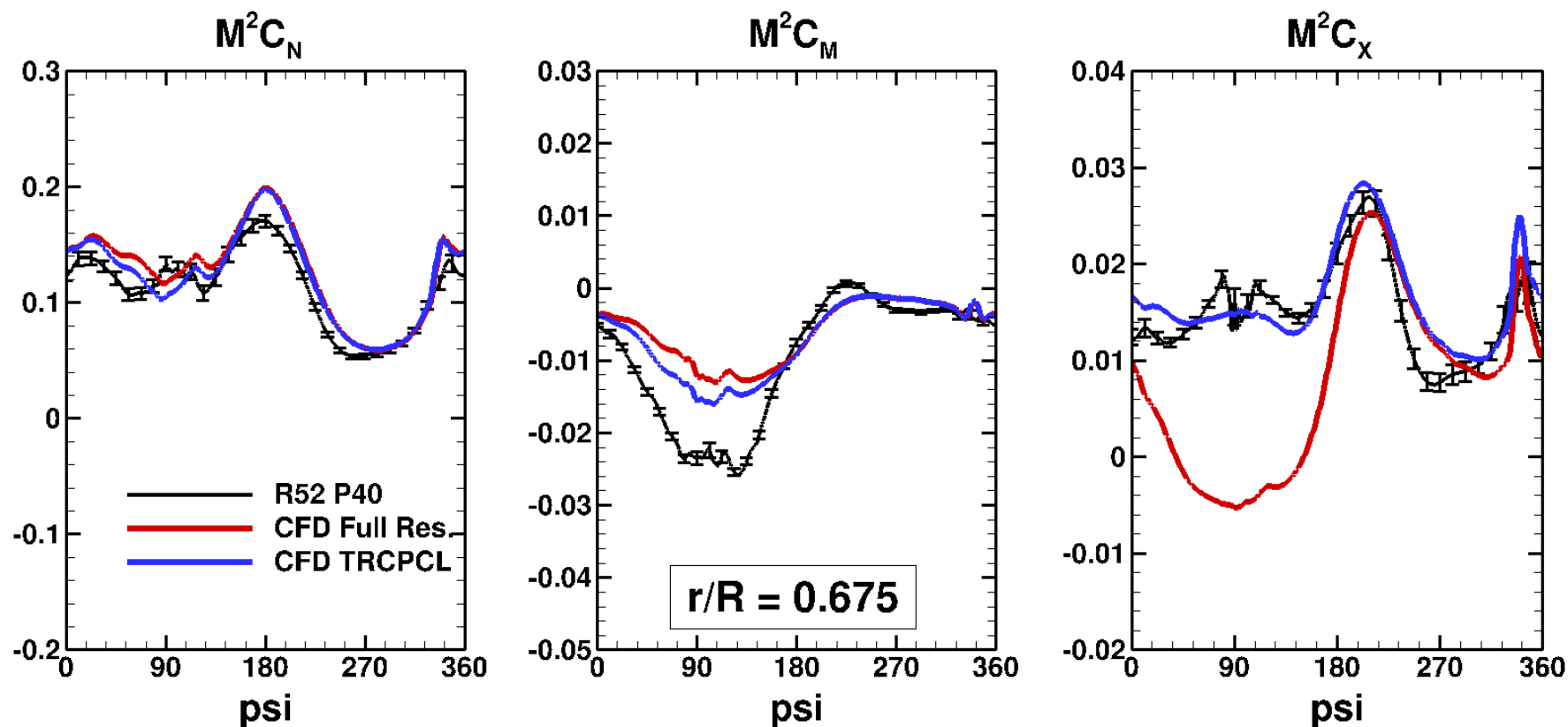
Effect of integration method Free-air rotor with LRTA



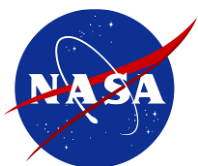


Sectional Loads $\mu=0.37$

Effect of integration method Free-air rotor with LRTA

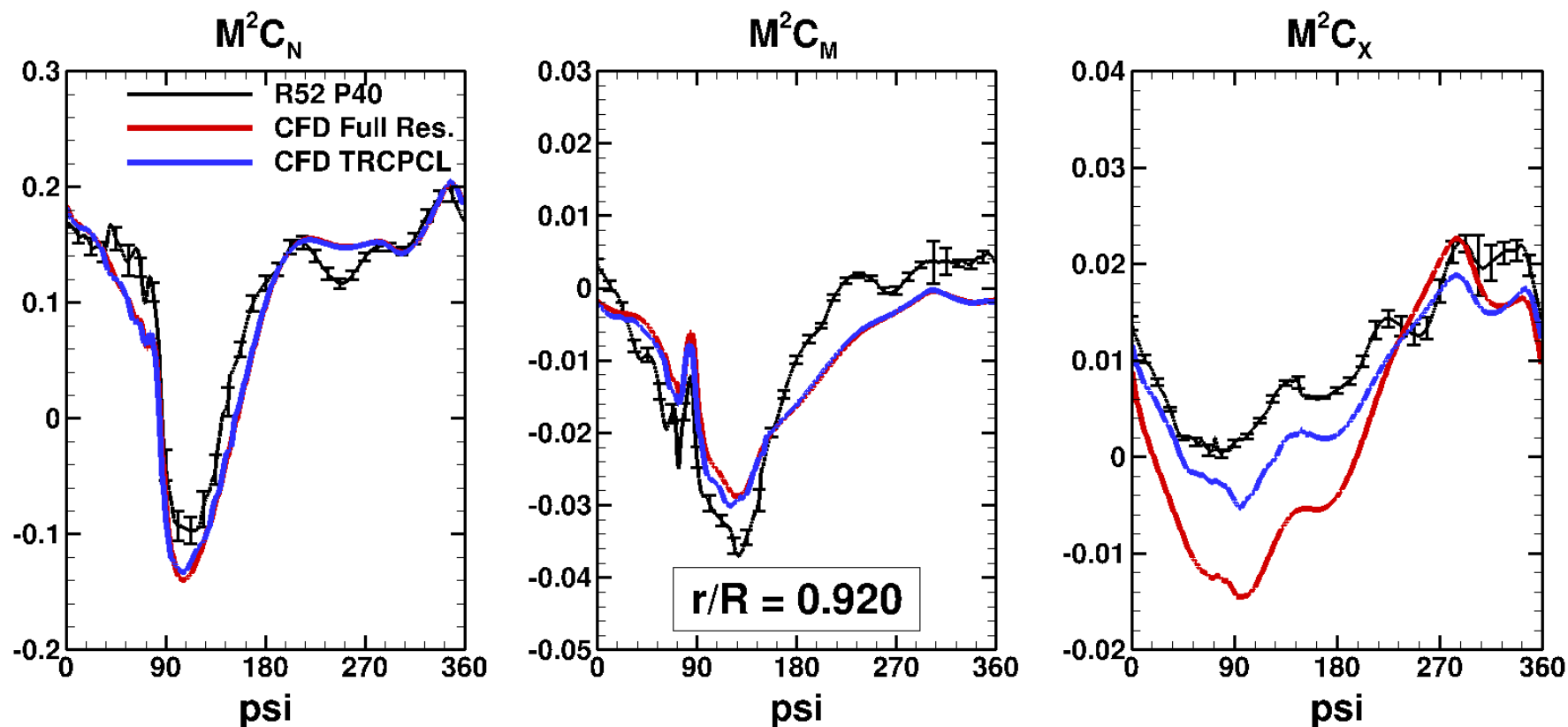


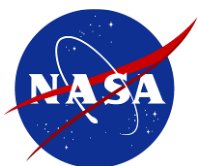
– Small number of operational pressure transducers (8) on upper surface



Sectional Loads $\mu=0.37$

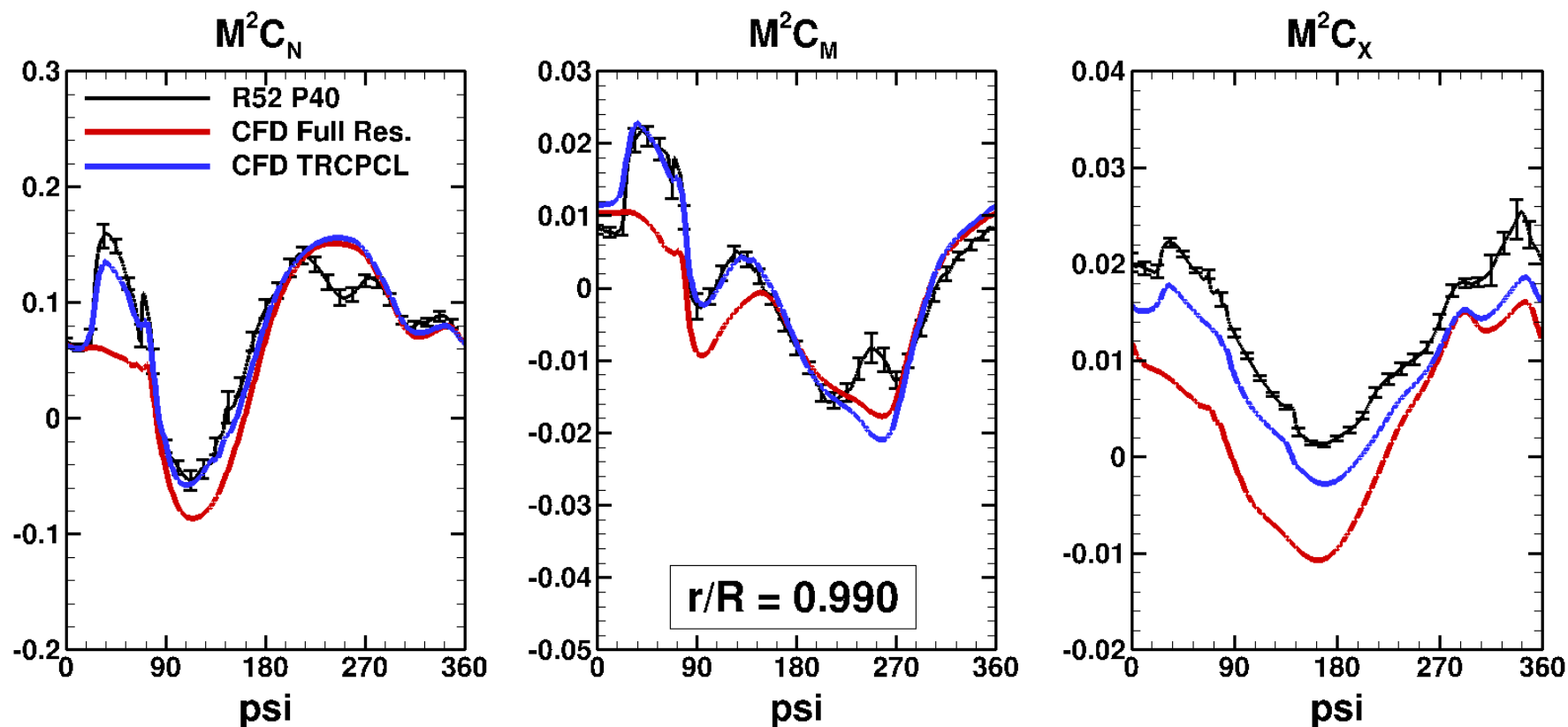
Effect of integration method
Free-air rotor with LRTA



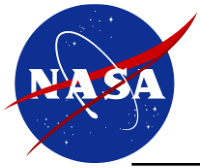


Sectional Loads $\mu=0.37$

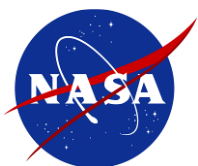
Effect of integration method Free-air rotor with LRTA



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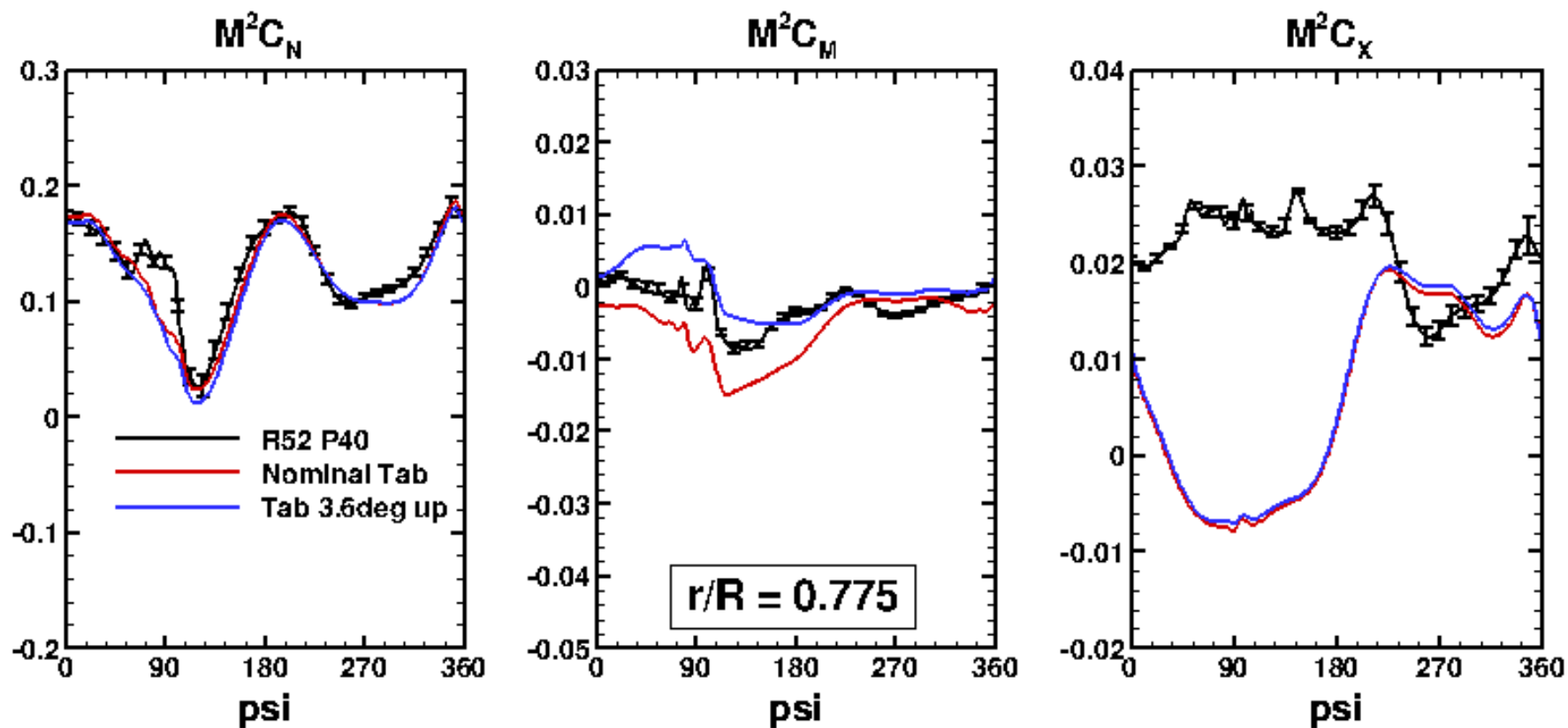


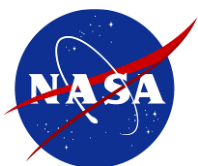
Sectional Pressures $\mu=0.37$



Sectional Loads $\mu=0.37$

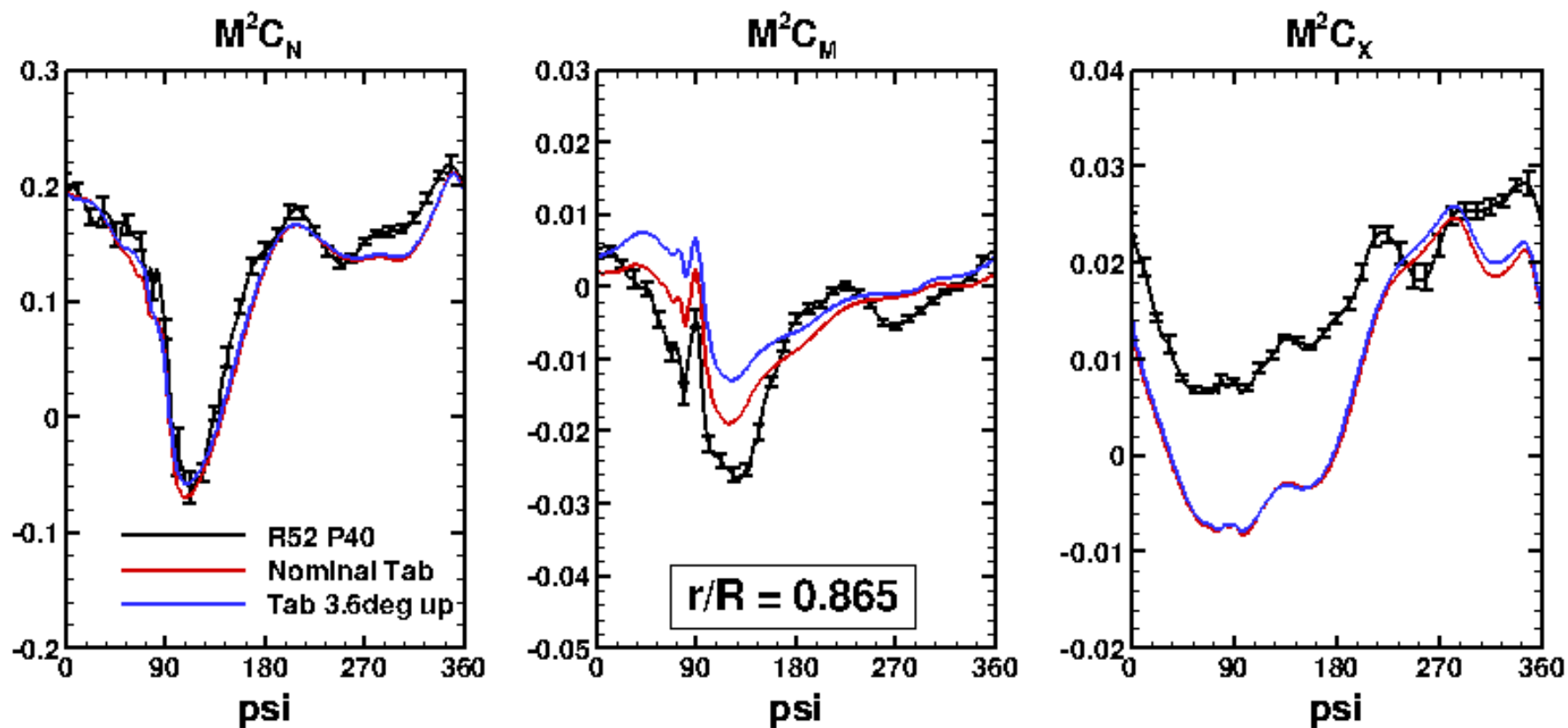
Effect of tab deflections
Free-air rotor with LRTA





Sectional Loads $\mu=0.37$

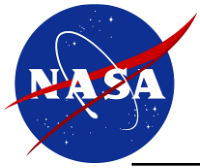
Effect of tab deflections
Free-air rotor with LRTA





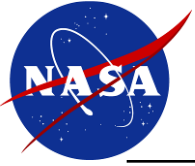
Concluding Remarks

- Performed FUN3D/CAMRADII loose-coupling computations for the 1-g level flight speed sweep
- CFD/CSD rotor performance, sectional airloads and pressure predictions compared to wind tunnel data
 - Trends match wind tunnel data & consistent with published CFD/CSD results
 - Little sensitivity to tunnel modeling indicate that the shaft angle corrections adequately compensate for wall influence
 - Small sensitivity to LRTA modeling which increases with advance ratio
 - Sensitivity of outboard sectional pitching moment at $\mu=0.37$ to trim tab deflections
- Despite precise knowledge of rotor trim loads and flight conditions, sectional loads and pressures for $\mu=0.37$ show similar trends to flight test comparisons



Next Steps

- Thrust Collective sweep



Acknowledgments

- Ethan Romander (NASA ARC) for providing the update to CAMRADII models
- Tom Norman (NASA ARC) for reviewing data correlations
- UH-60A Airloads Wind Tunnel Test Team