



# **Initial FUN3D/CAMRADII Results for the UH-60A Airloads NFAC Test Configuration**

Elizabeth M. Lee-Rausch

Robert T. Biedron

NASA Langley Research Center

UH-60A Airloads Workshop, NASA Ames Research Center

March 8–9, 2012



# Acknowledgments

---

- Ethan Romander (NASA ARC) for providing the update to CAMRADII models
- Tom Norman (NASA ARC) for reviewing data correlations



# Outline

---

- Motivation and Methodology
- Comparison of FUN3D/CAMRADII loose-coupling results with UH60A Airloads NFAC speed sweep data
  - Rotor forces and moments
  - Sectional airloads
  - Chordwise pressure distributions
- Concluding Remarks and Next Steps



# 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:
  - Speed sweep
  - Collective Sweep
  - Slowed rotor
- Comprehensive test measurements including:
  - Balance loads\*
  - Control settings\*
  - Blade deflection\*
  - Sectional airloads (pressures) at 8 radial locations
  - Structural loads



\*Measurement not available from flight test



## FUN3D/CAMRADII Model

---

- FUN3D model (baseline from flight test)
  - Isolated rotor grid
  - Mixed-element overset mesh with 15 million nodes (baseline)
  - 1 degree azimuth per time step
  - Standard Spalart-Allmaras turbulence model
  - Loosely-coupled with CAMRADII for aeroelastics/trim
- CAMRADII model (Hyeonsoo Yeo)
  - Same structural model as used for flight test
  - Some changes based on Ethan's recommendation
    - o Increased number of radial aero. panels from 21 to 100
    - o Increased azimuthal resolution from 24 to 36

Did not change models significantly for initial wind tunnel simulations to provide a bridge back to flight test correlations



## Current Wind Tunnel/CFD Correlations

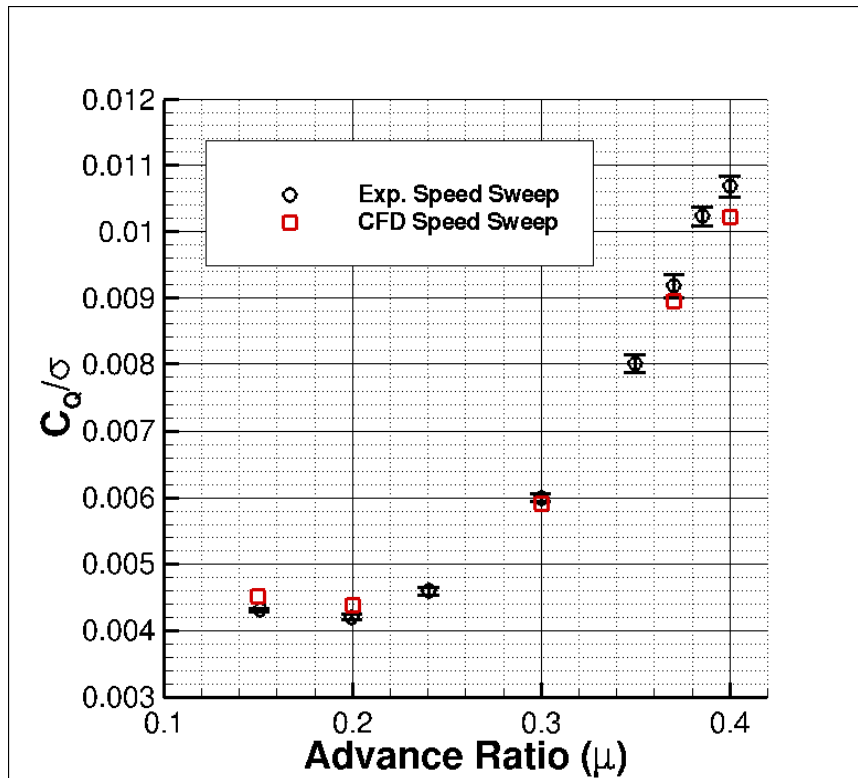
---

- Wind tunnel test conditions and data from the official website
- Results are presented in “CFD” reference frame
  - 0 azimuth is CFD/CSD reference (7 degree offset from wind tunnel data)
  - Rolling moment is CFD positive right wing down
- Fixed-system derived trim angles (experimental data corrected for azimuth reference) are compared to CSD pitch-link joint
- Experimental standard deviation shows the variability of the parameter as a function of azimuth position
- CFD sectional loads are computed with full CFD resolution
- No means removed in any of the data correlations

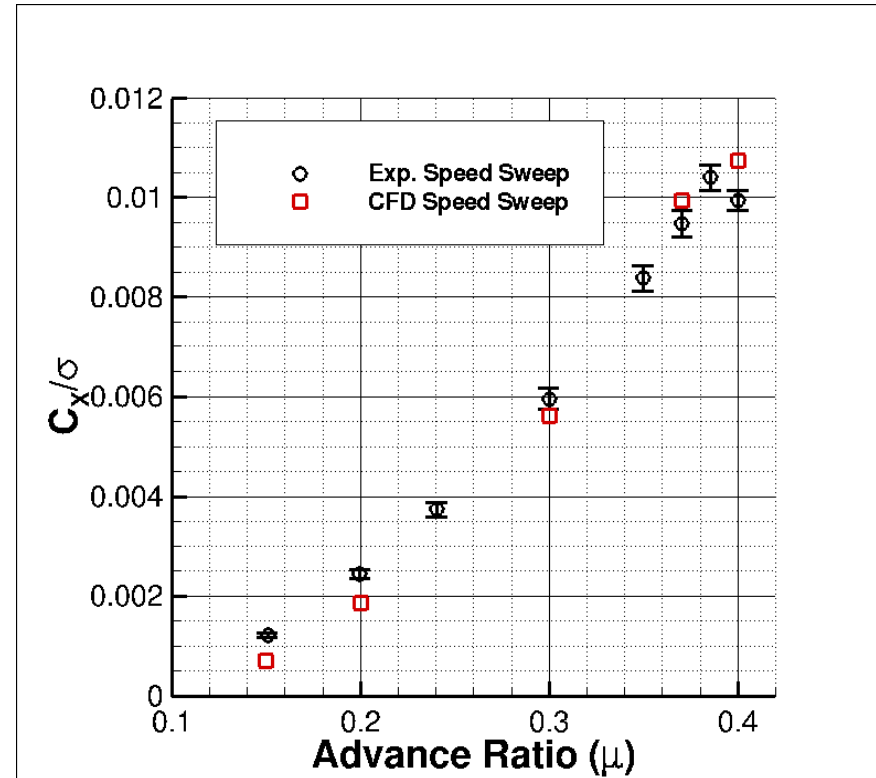


# Preliminary Speed Sweep Results

Rotor Balance Power/Solidity



Rotor Balance X-Force /Solidity

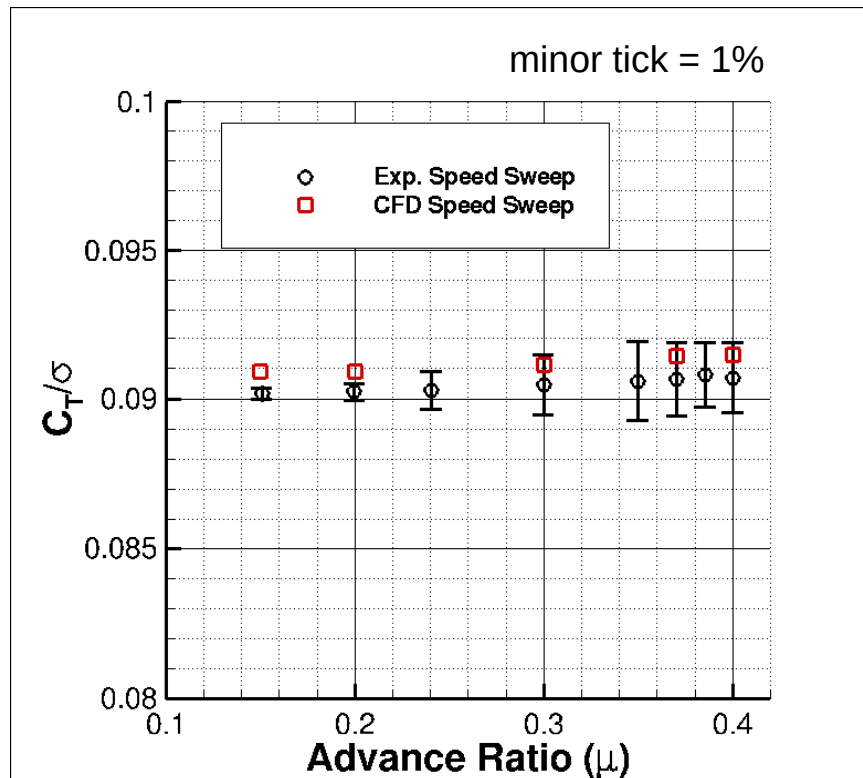


- Increase in forward speed (advance ratio) at nearly constant rotor thrust
- Rotor power (torque) and propulsive predictions trend similar to experiment and OVERFLOW results

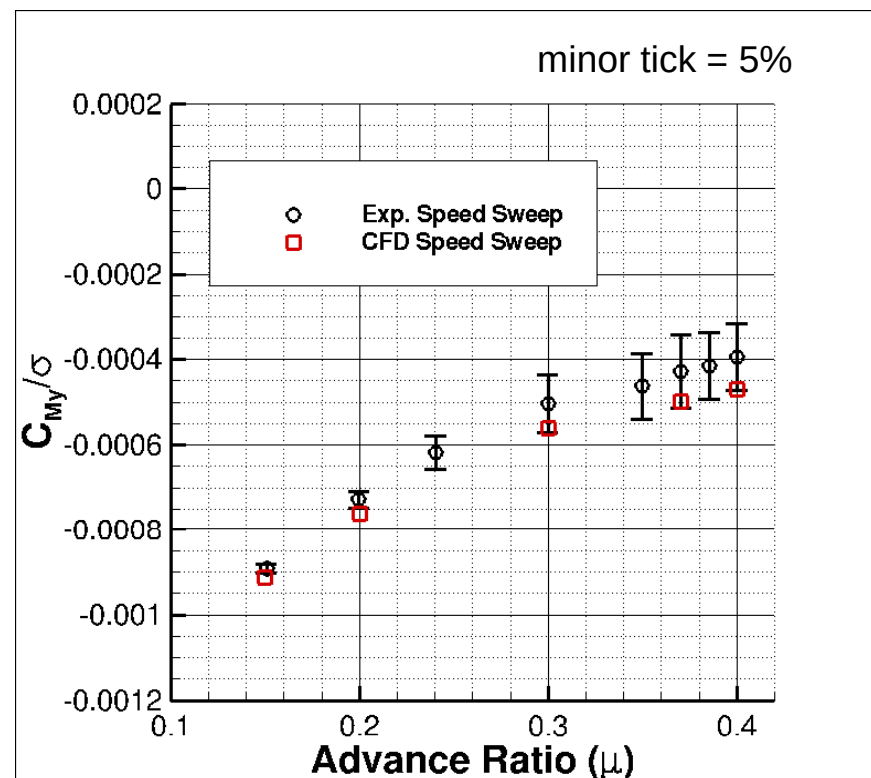


# Preliminary Speed Sweep Results

Rotor Balance Thrust/Solidity



Rotor Balance Pitching Moment/Solidity

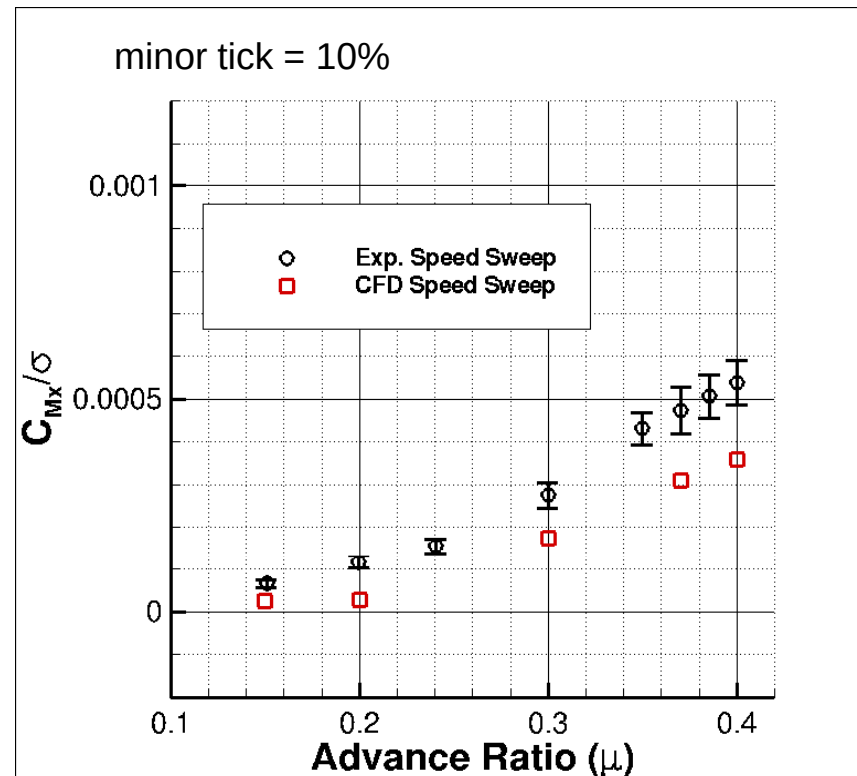


- Rotor trim done in CAMRADII at lower resolution(time/space) than CFD
- CAMRADII trim values match wind tunnel data to within plotting accuracy



# Preliminary Speed Sweep Results

## Rotor Balance Rolling Moment/Solidity

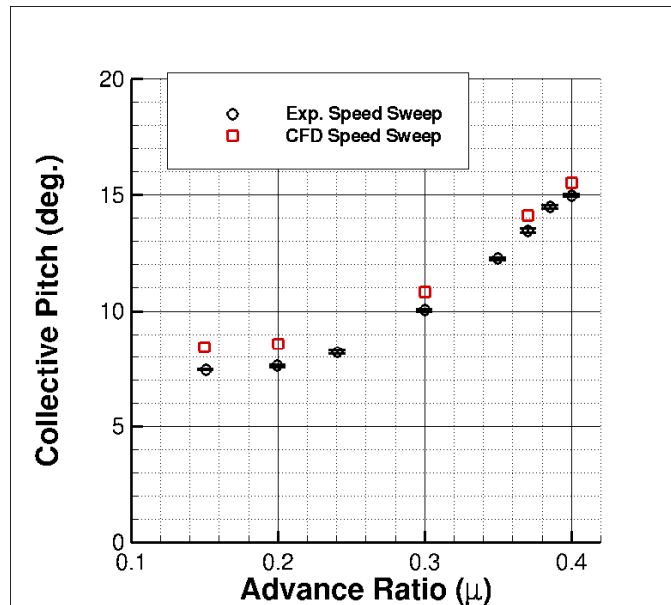


- Thrust match between CAMRADII and CFD less than 1% but moment differences are higher, which could have impact on rotor power/propulsion
- Effort underway to increase CAMRADII time/space resolution (Ethan Romander, ARC)

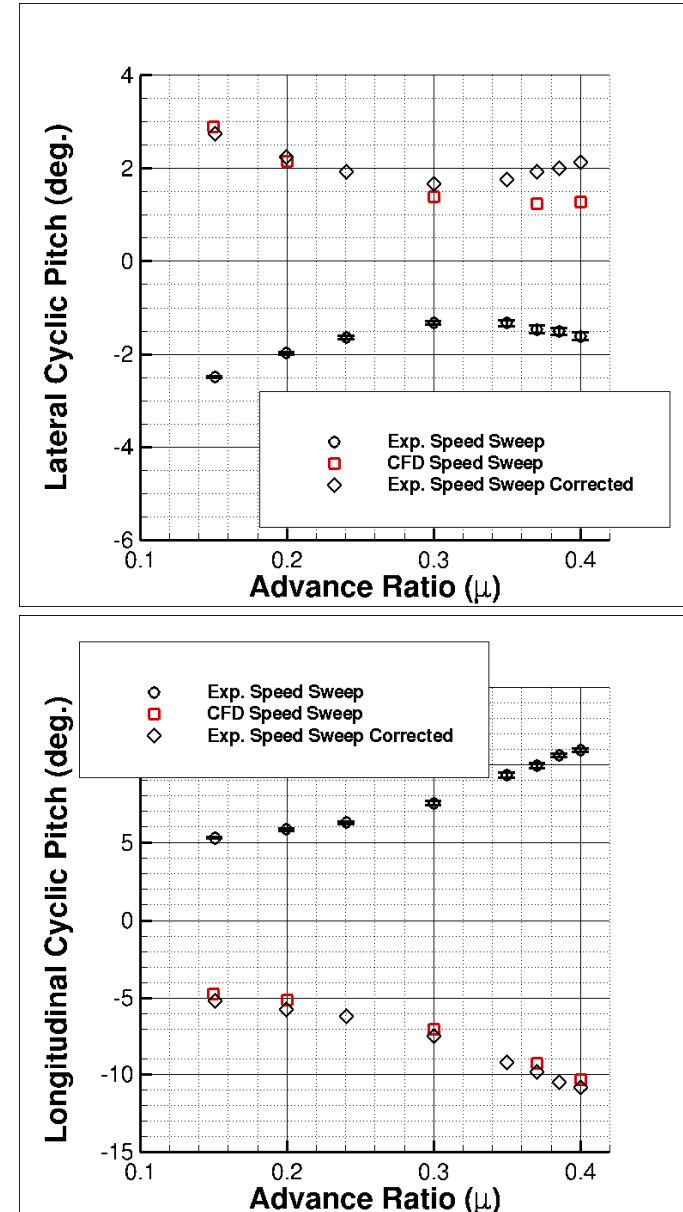


# Preliminary Speed Sweep Results

## Fixed-System Control Angles



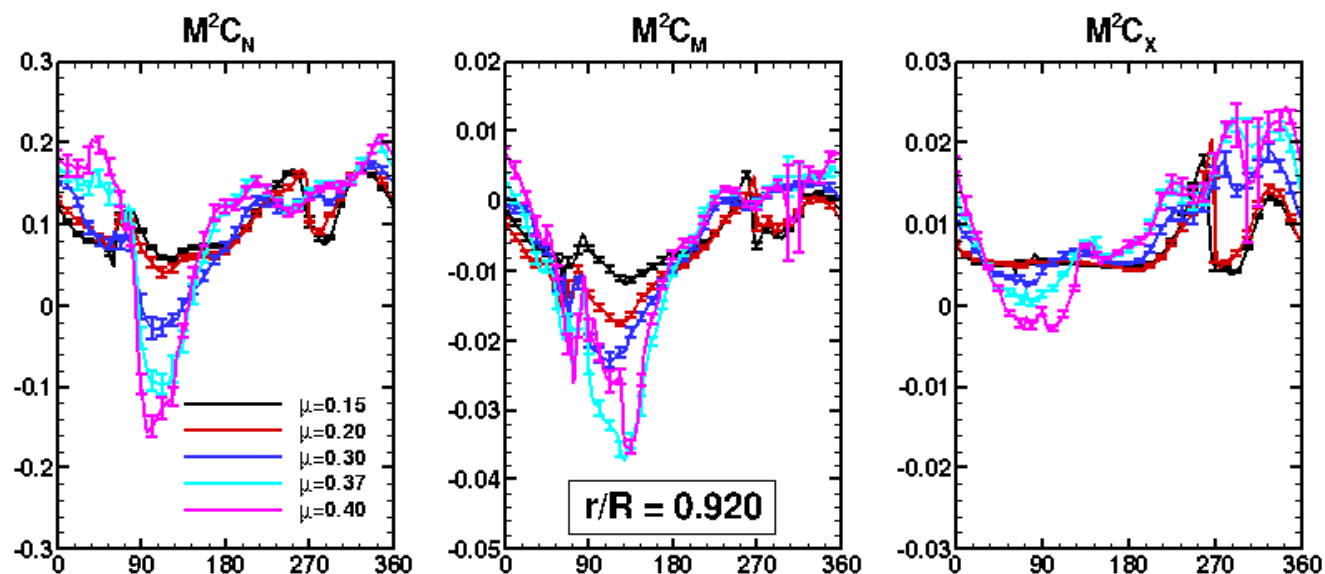
Wind tunnel data “corrected” for difference in azimuth reference



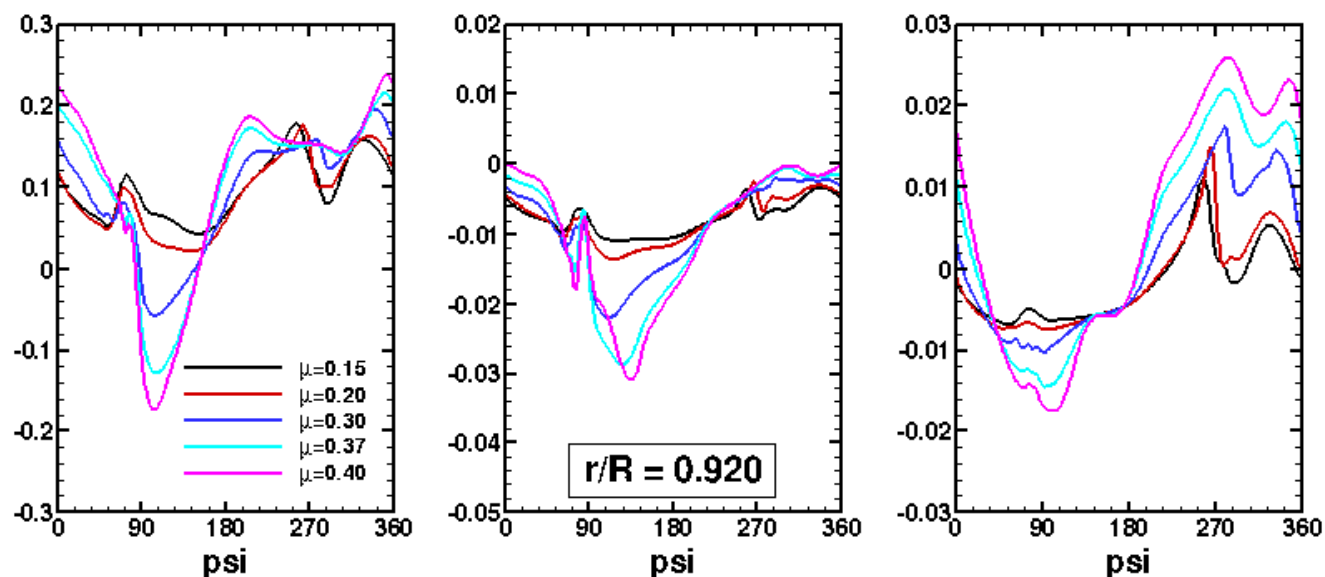


# Preliminary Speed Sweep Results

Wind Tunnel Data



CFD Results

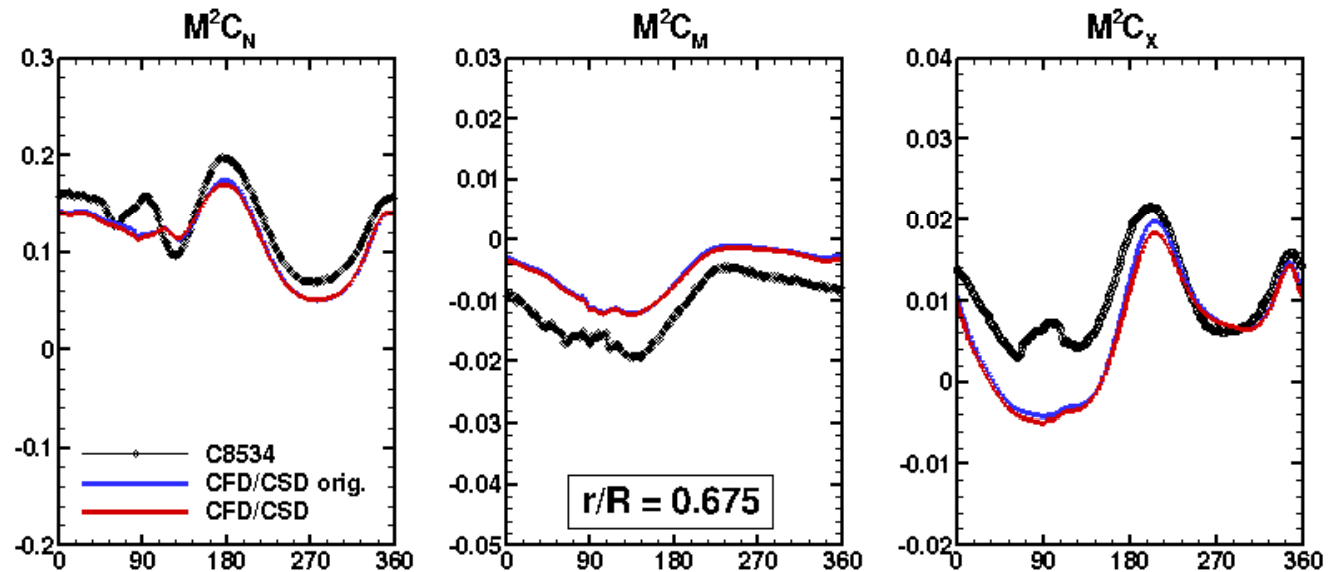


Note: CFD integration at full resolution

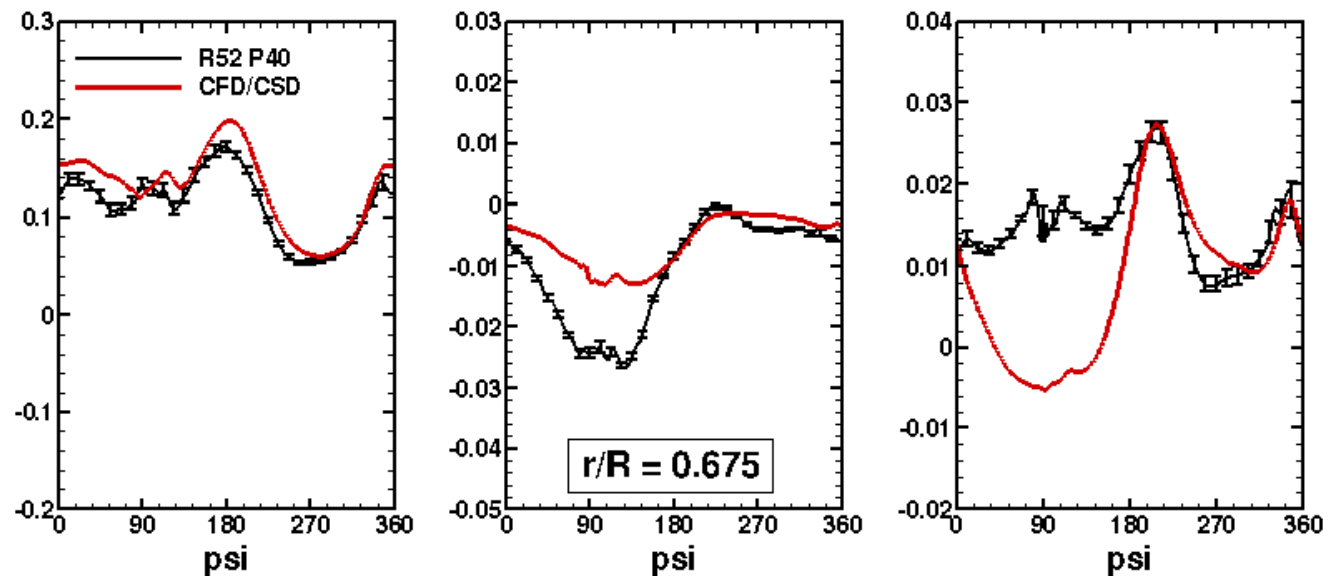


# Comparison of Sectional Loads to C8534

Flight Test Data



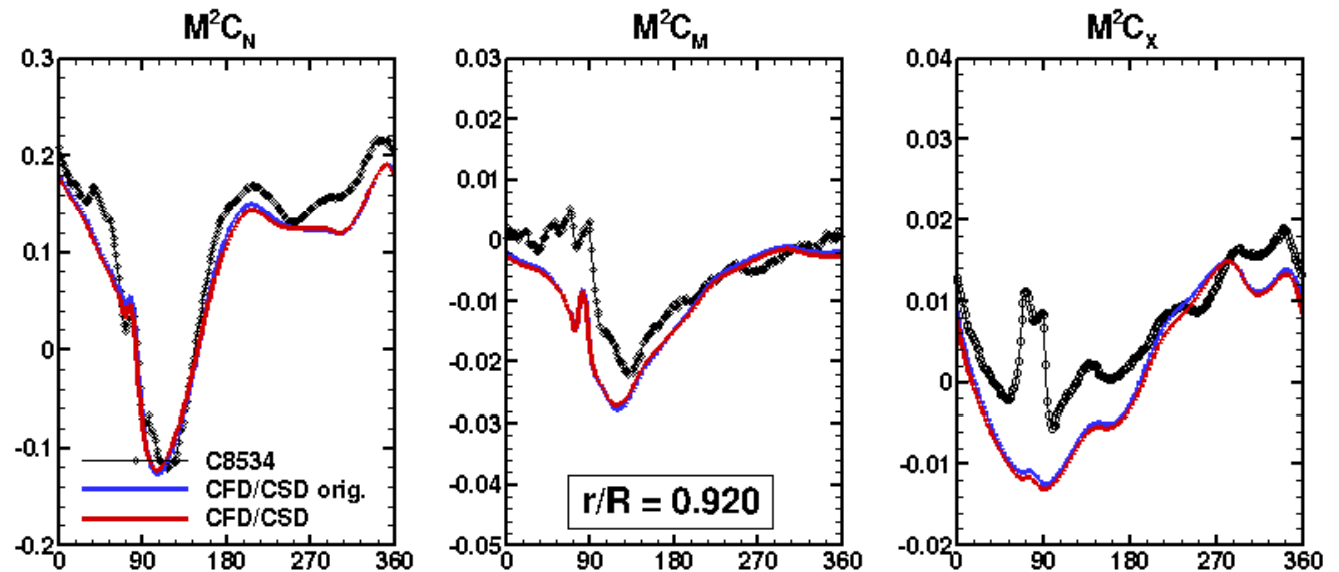
Wind Tunnel Data



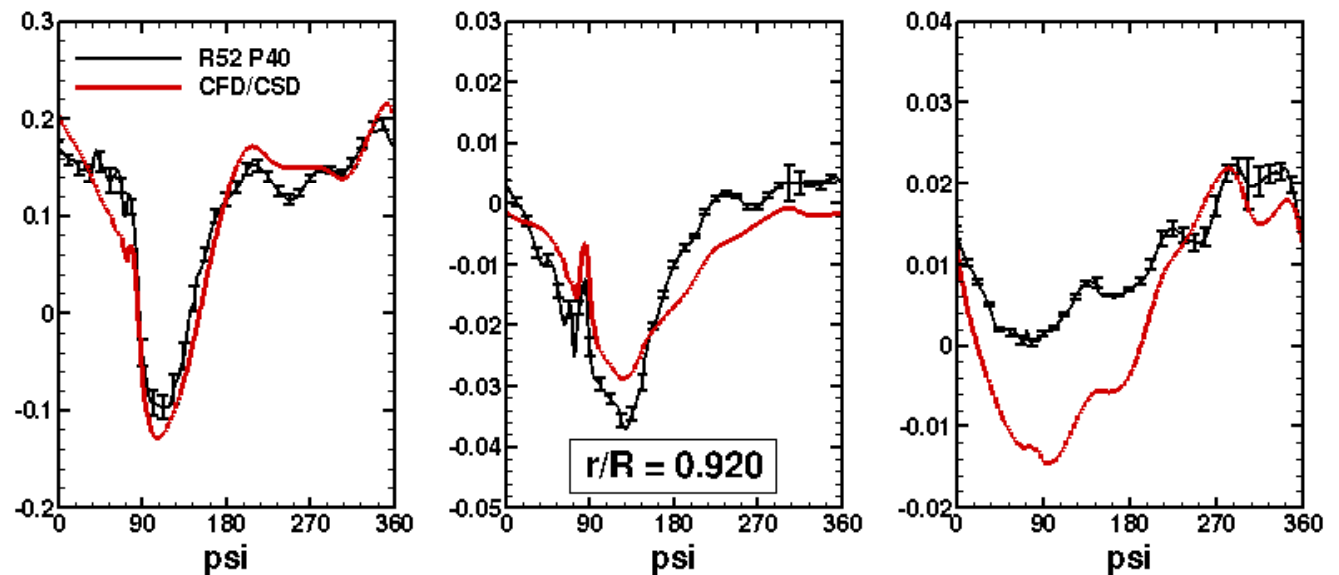


# Comparison of Sectional Loads to C8534

Flight Test Data

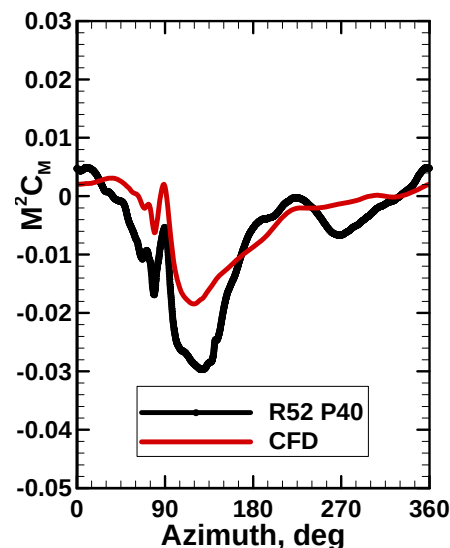
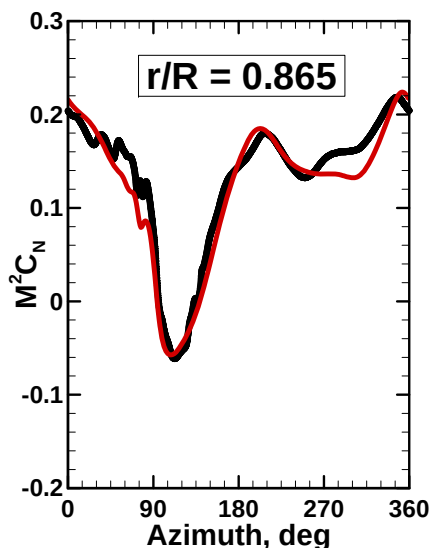
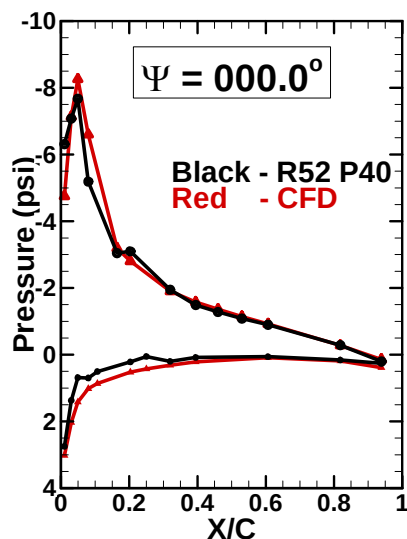


Wind Tunnel Data

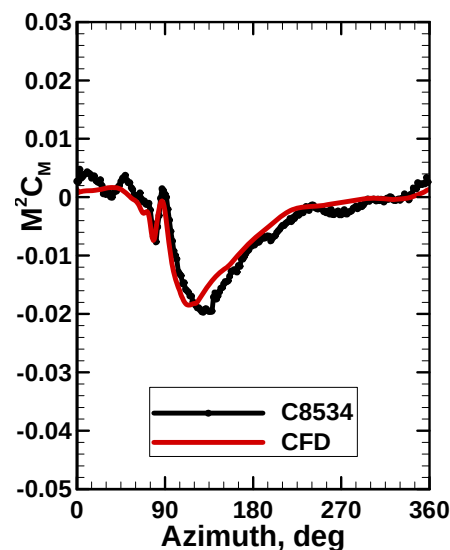
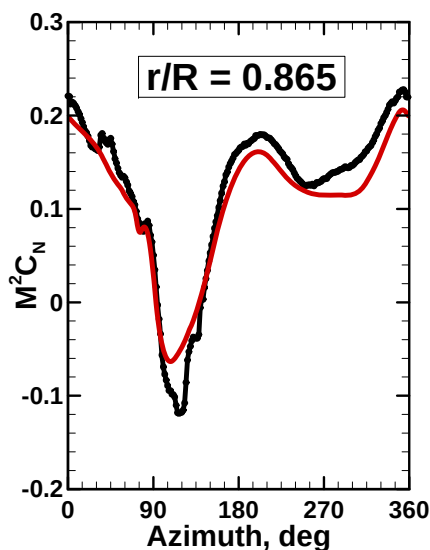
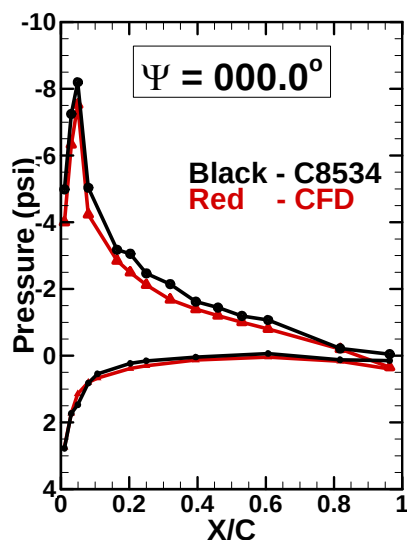




# Sectional Pressure/Airloads Correlation

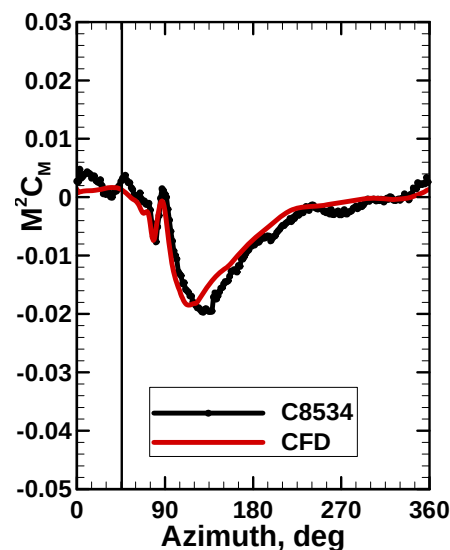
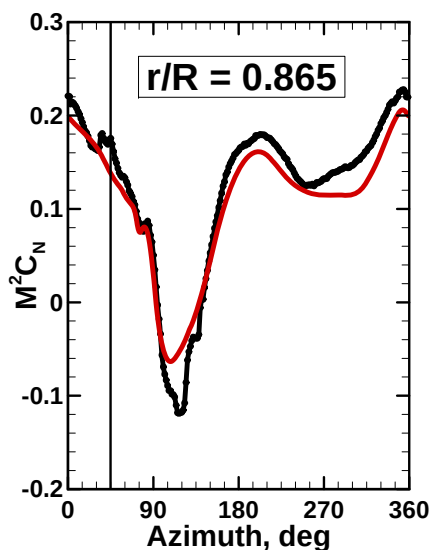
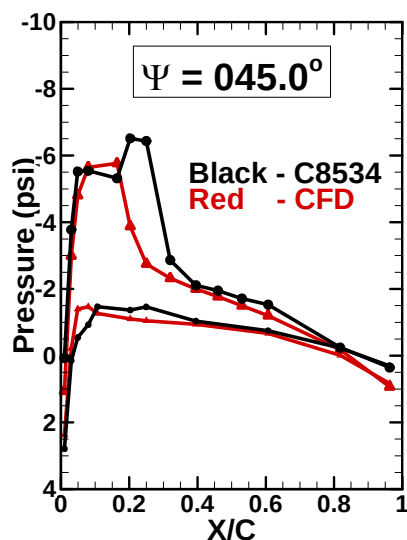
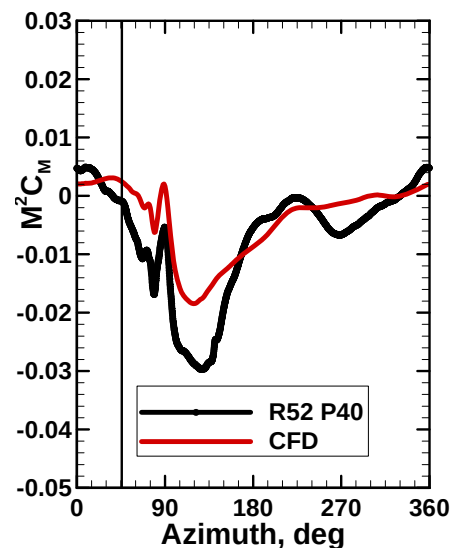
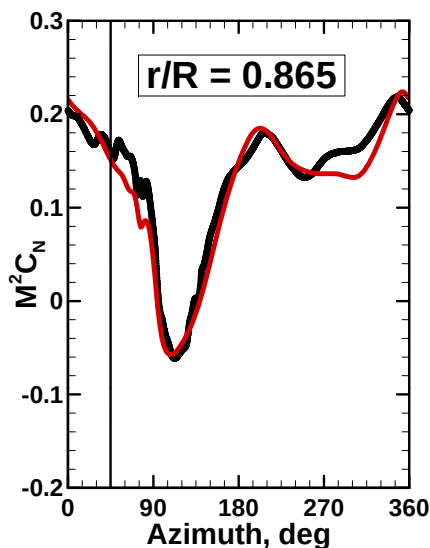
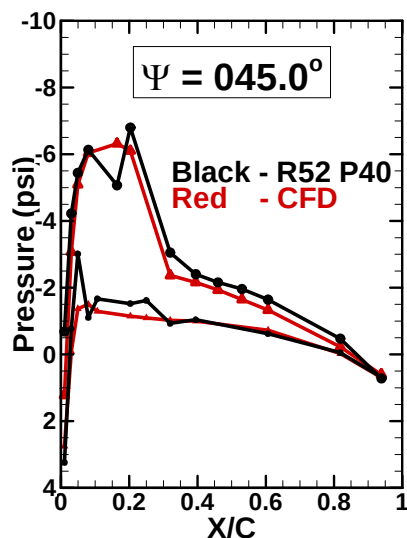


PM +nose up  
Solid lower surf  
Open upper surf



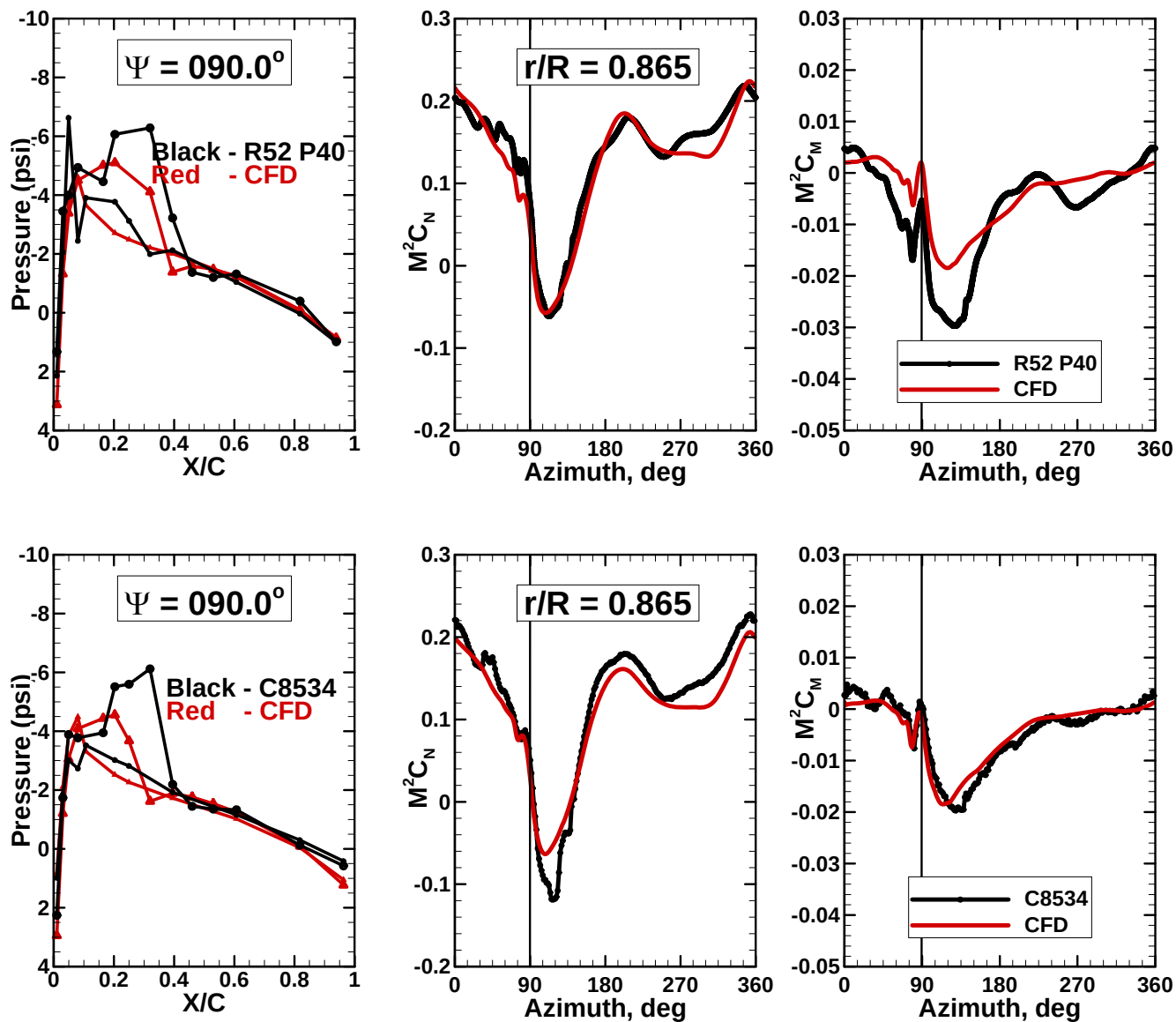


# Sectional Pressure/Airloads Correlation



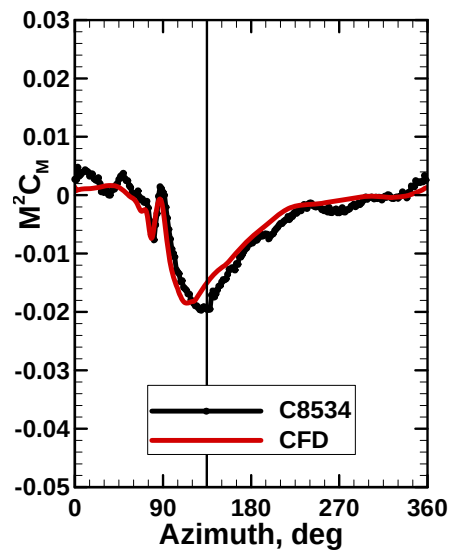
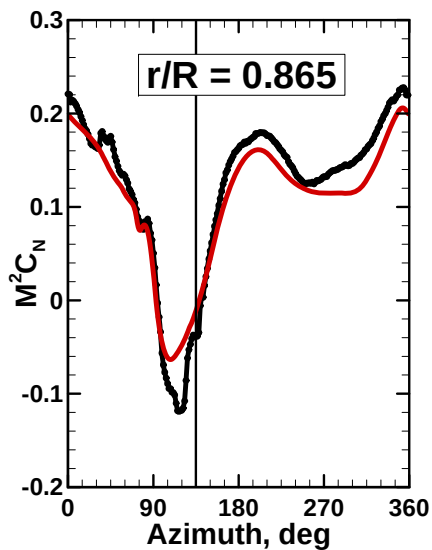
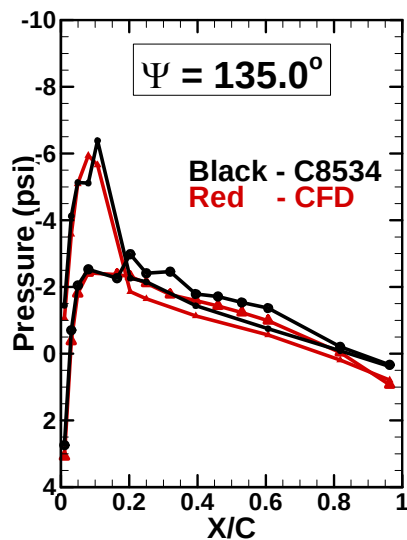
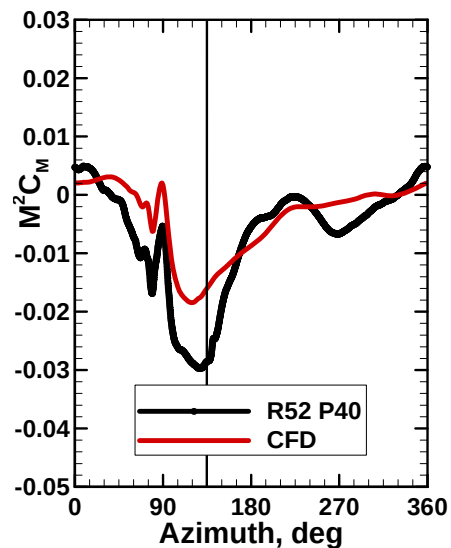
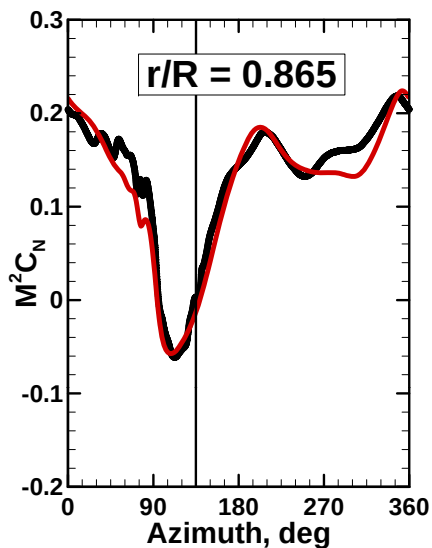
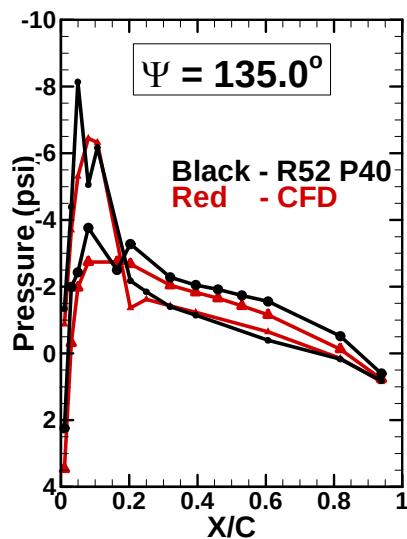


# Sectional Pressure/Airloads Correlation



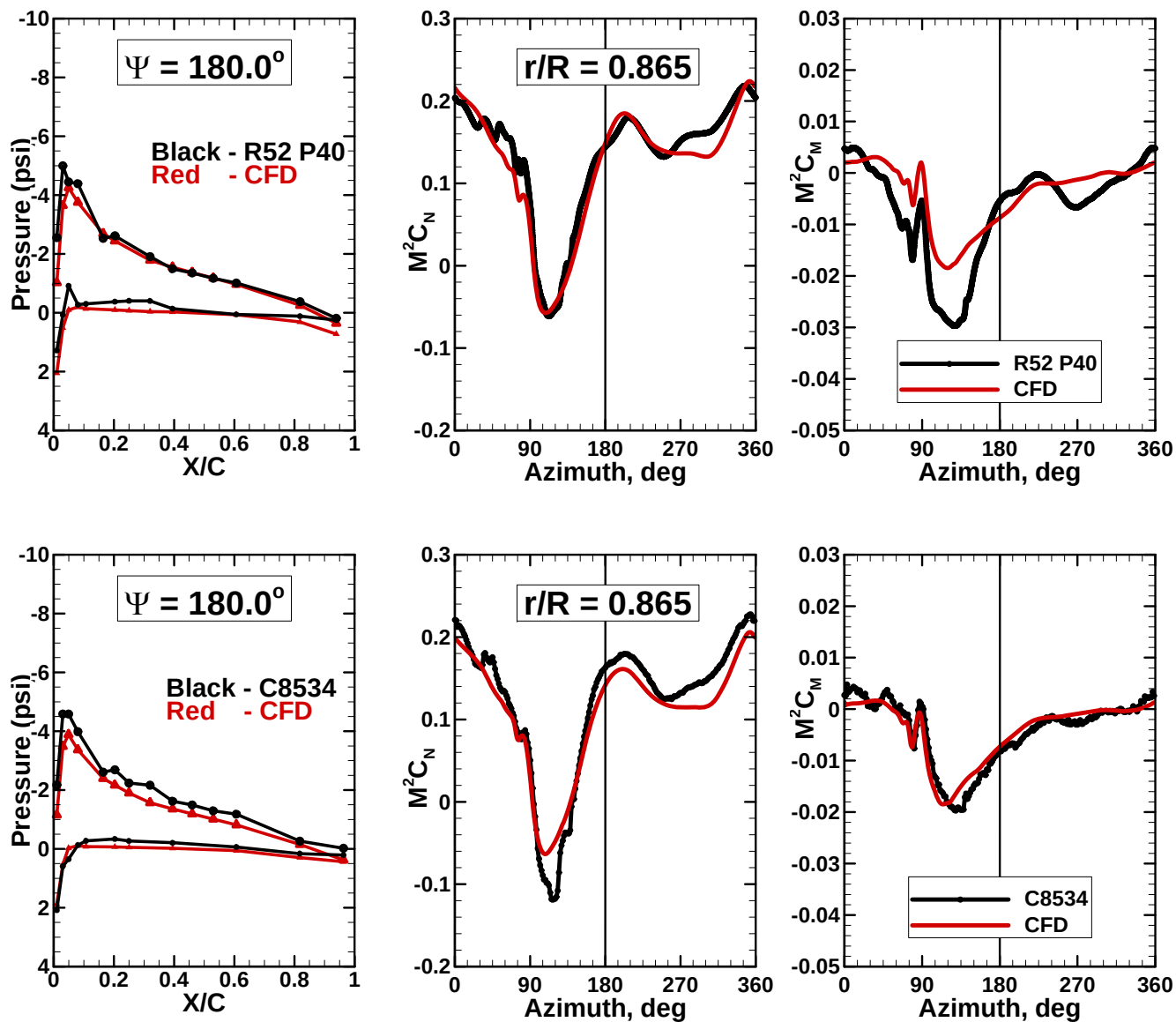


# Sectional Pressure/Airloads Correlation



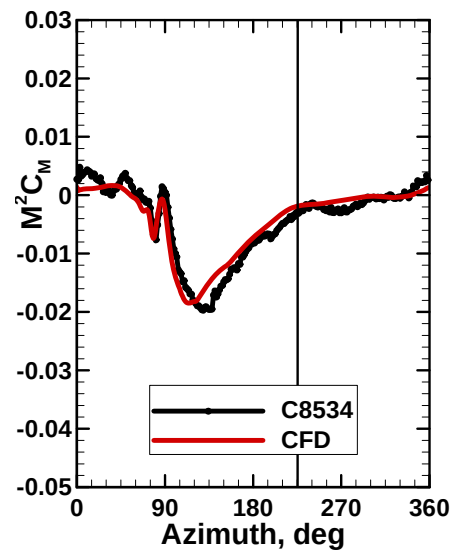
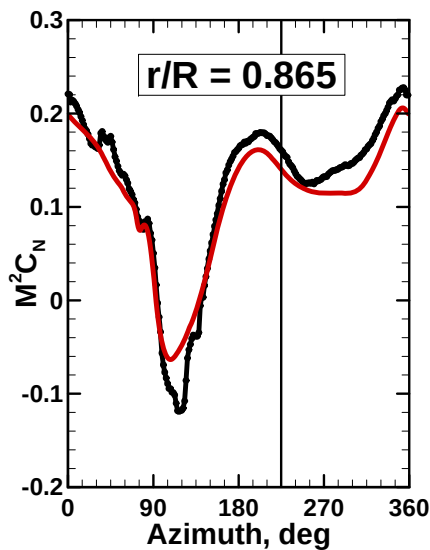
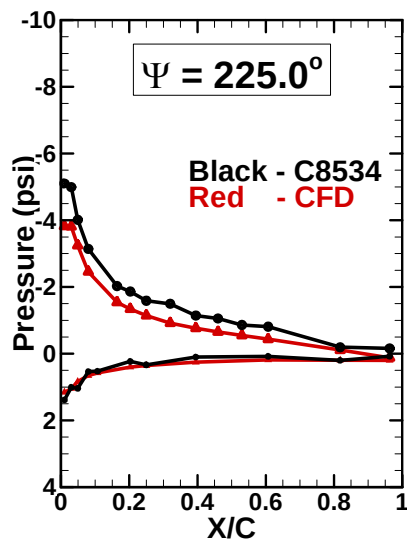
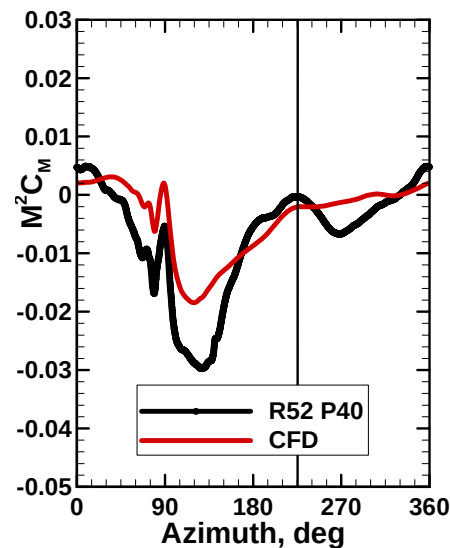
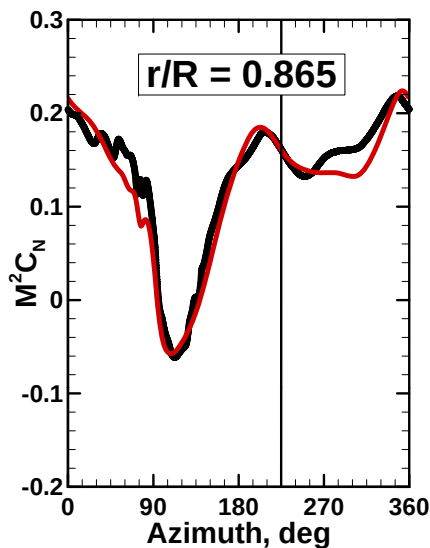
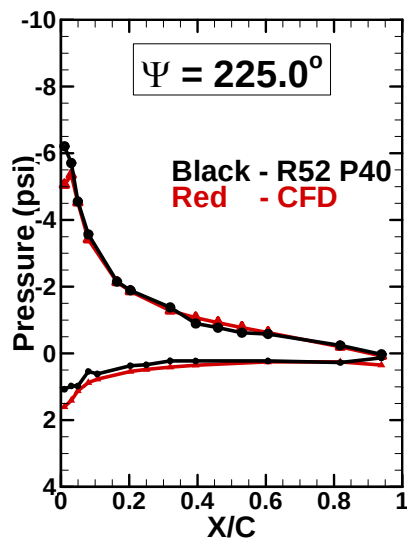


# Sectional Pressure/Airloads Correlation



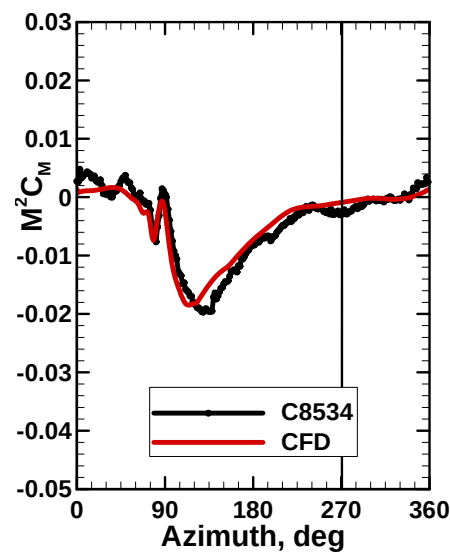
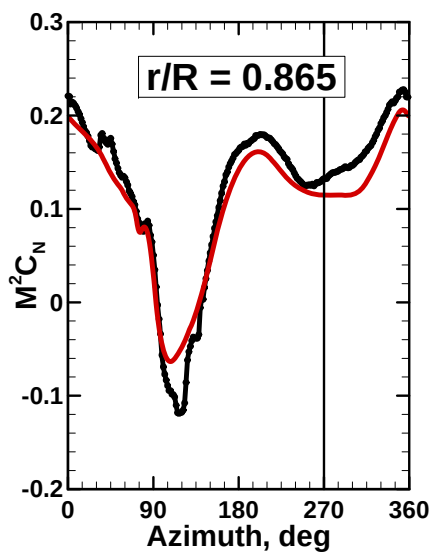
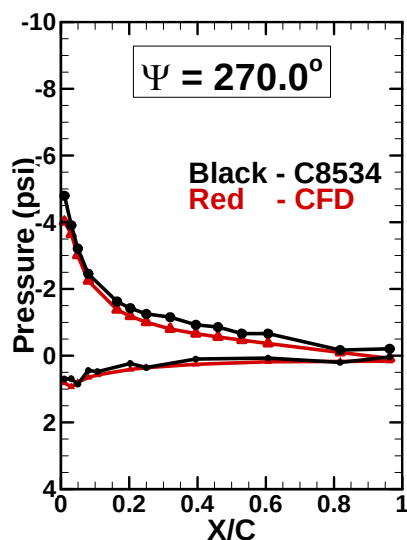
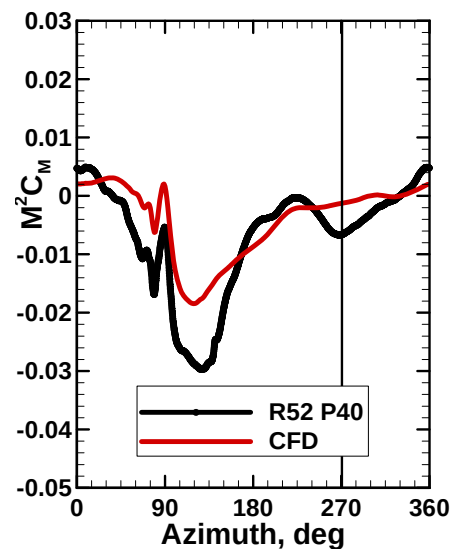
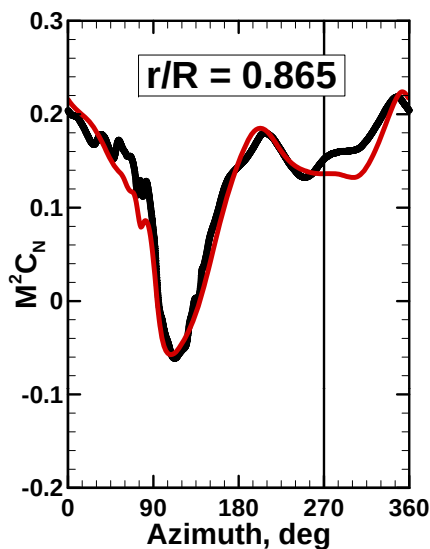
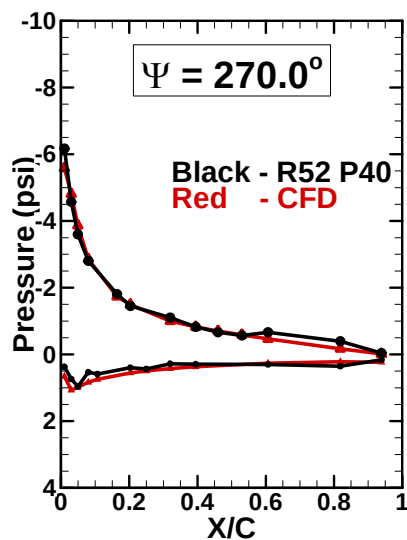


# Sectional Pressure/Airloads Correlation



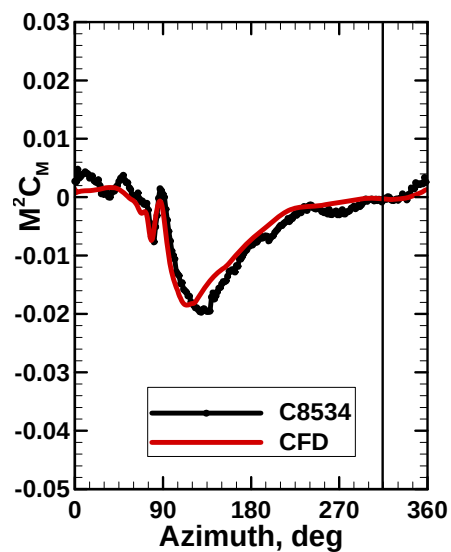
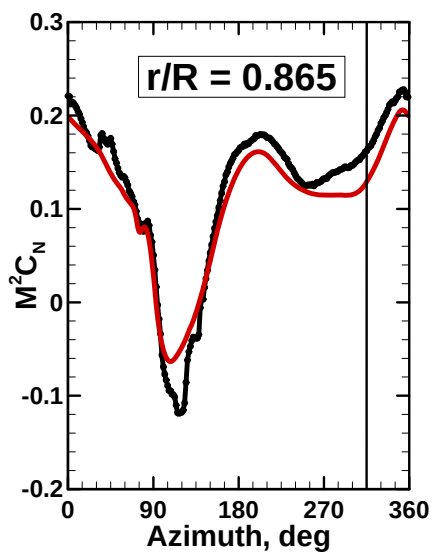
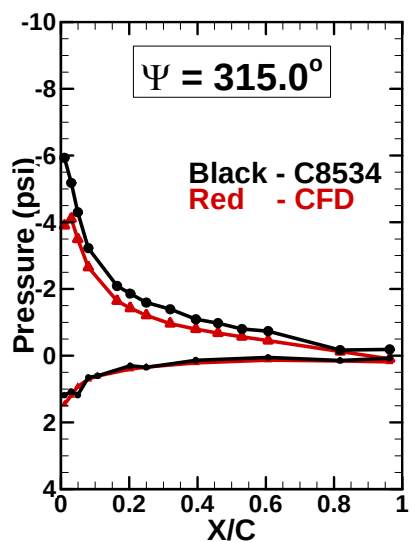
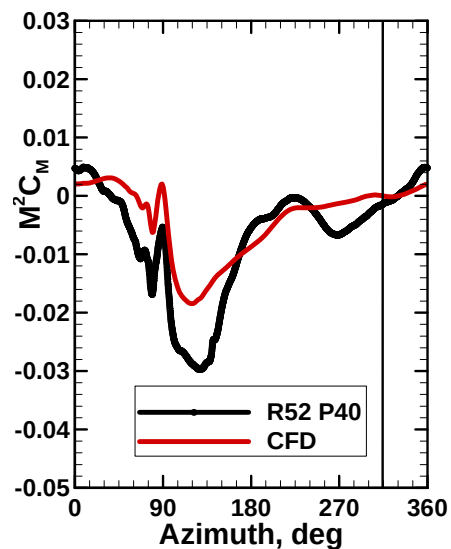
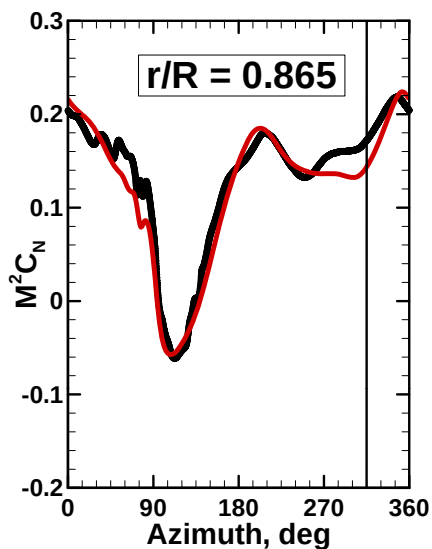
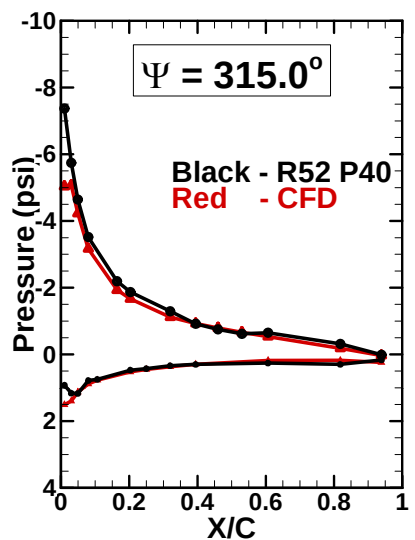


# Sectional Pressure/Airloads Correlation





# Sectional Pressure/Airloads Correlation





## Concluding Remarks

---

- Performed initial FUN3D/CAMRADII loose-coupling computations for the Airloads Wind Tunnel Test speed sweep
- Comparisons of CFD/CSD rotor power, propulsive force and control angle predictions are reasonable
  - Overall trends match wind tunnel data
  - Overall trends match Overflow results
- Moment conservation in the current CFD/CSD data exchange not adequate
- Comparisons of CFD/CSD sectional loads for C8534 and R52 P40 show similar trends
- Comparisons of CFD/CSD pressures for C8534 and R52 P40 show similar trends



## Next Steps

---

- Improve force/moment conservation in loose-coupling process
- Compute sectional loads with the post-processing routines used for wind tunnel data
- Compare with the deflection data when available
- Add geometric fidelity to CFD model
  - LRTA body/hub
  - Wind tunnel floor/walls
- Collective sweep