

Unstructured-Grid UH-60A Simulations Using FUN3D/CAMRAD

Robert T. Biedron

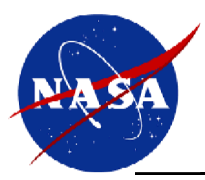
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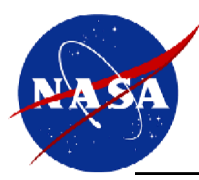
UH-60A Airloads Workshop, Arlington, VA

August 19-20, 2010



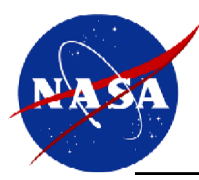
Outline

- Action Items From February
- C9017 High Thrust Results
 - Grid effects
- Concluding Remarks



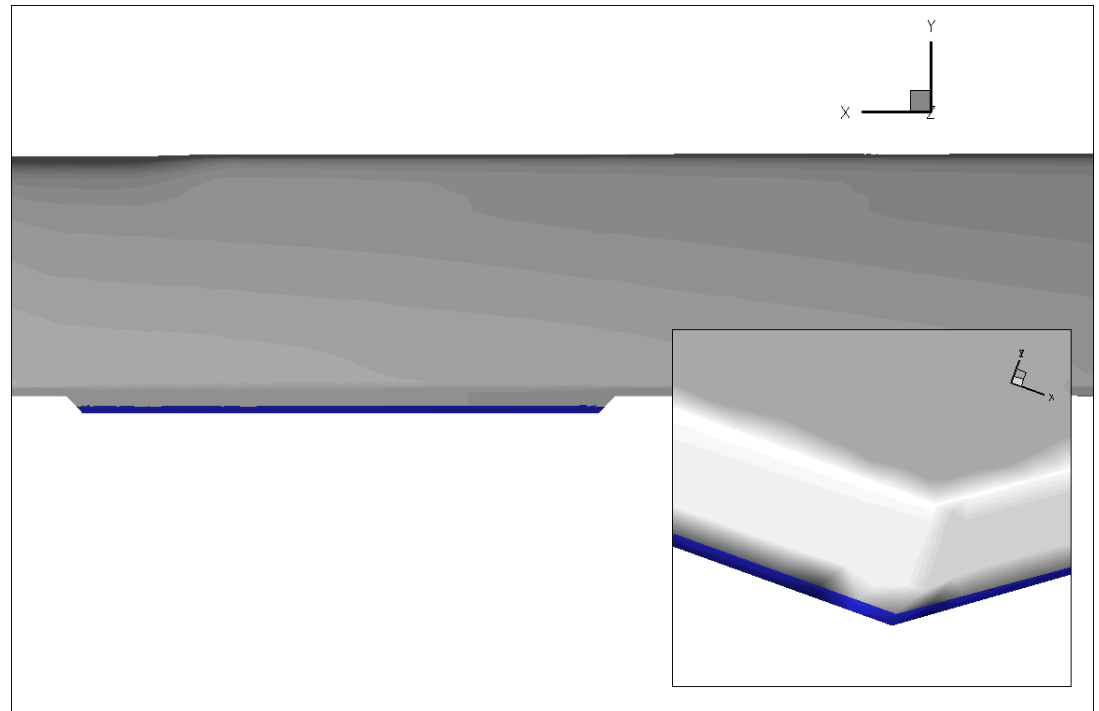
Action Items From February

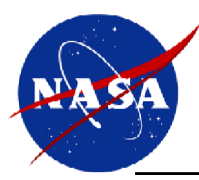
- Convert CFD/CSD results to PD/B form for inclusion in “The Book”
 - **Done**, but Bill Bousman is no longer updating the book
 - Current results (aero and structural loads) plotted with PD/B dimensions and variable ranges
- Look at sensitivity to trim tab setting
 - **Currently underway**
 - Details next slide



Sensitivity To Trim Tab Setting

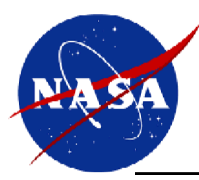
- Trailing edge treatment (sharp vs blunt/square) showed some sensitivity for computed results (Feb '10)
 - Sharpened TE also slightly changed local camber
 - Alan Egolf suggested +/- 2 deg trim tab range
- “Quick and Dirty” modification to tab in existing grid - actual trim tab much thinner
- Underway for C9020





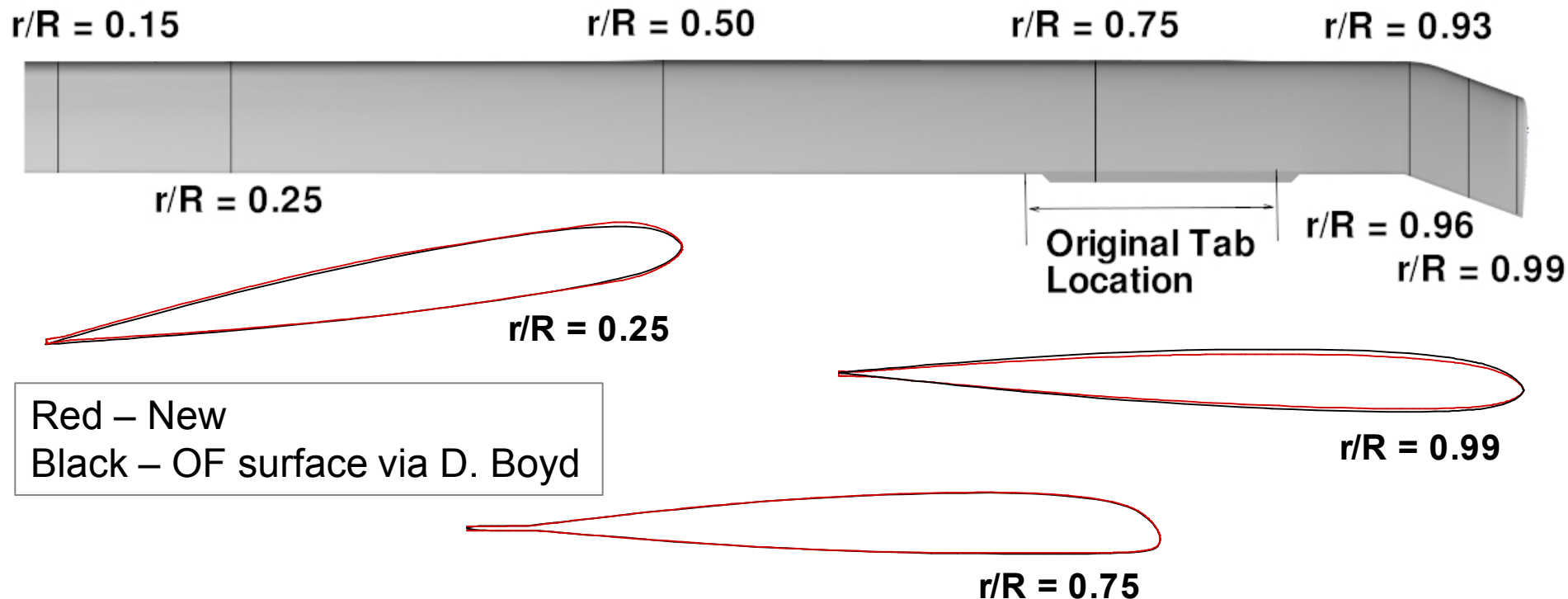
FUN3D / CAMRAD-II Simulations

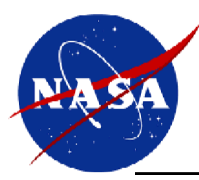
- Focus this time on C9017
 - Results / convergence sensitive to...almost anything
 - Rotor only
 - Pure tetrahedral and mixed-element meshes
 - Mixed-element meshes from tet mesh by merging tets in boundary layer into prisms; points unchanged
 - Mixed-element discretization should be more accurate for a given mesh size
 - 15M nodes; 1° azimuth / time step
 - Feb '09 trim targets; imposed as C_T/σ , roll and pitch moments
 - Use “new” blade definition from Alan Egolf



New vs. Old Blade Geometry

- Input from Alan Egolf to sort out blade geometry questions
 - Approx. 4 inch shift (outboard) in trim tab location
 - Blending “bump” inboard; slight thinning at very tip
 - “As-built” trailing edge – finite thickness, squared off

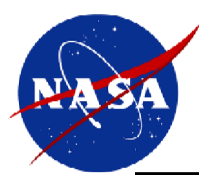




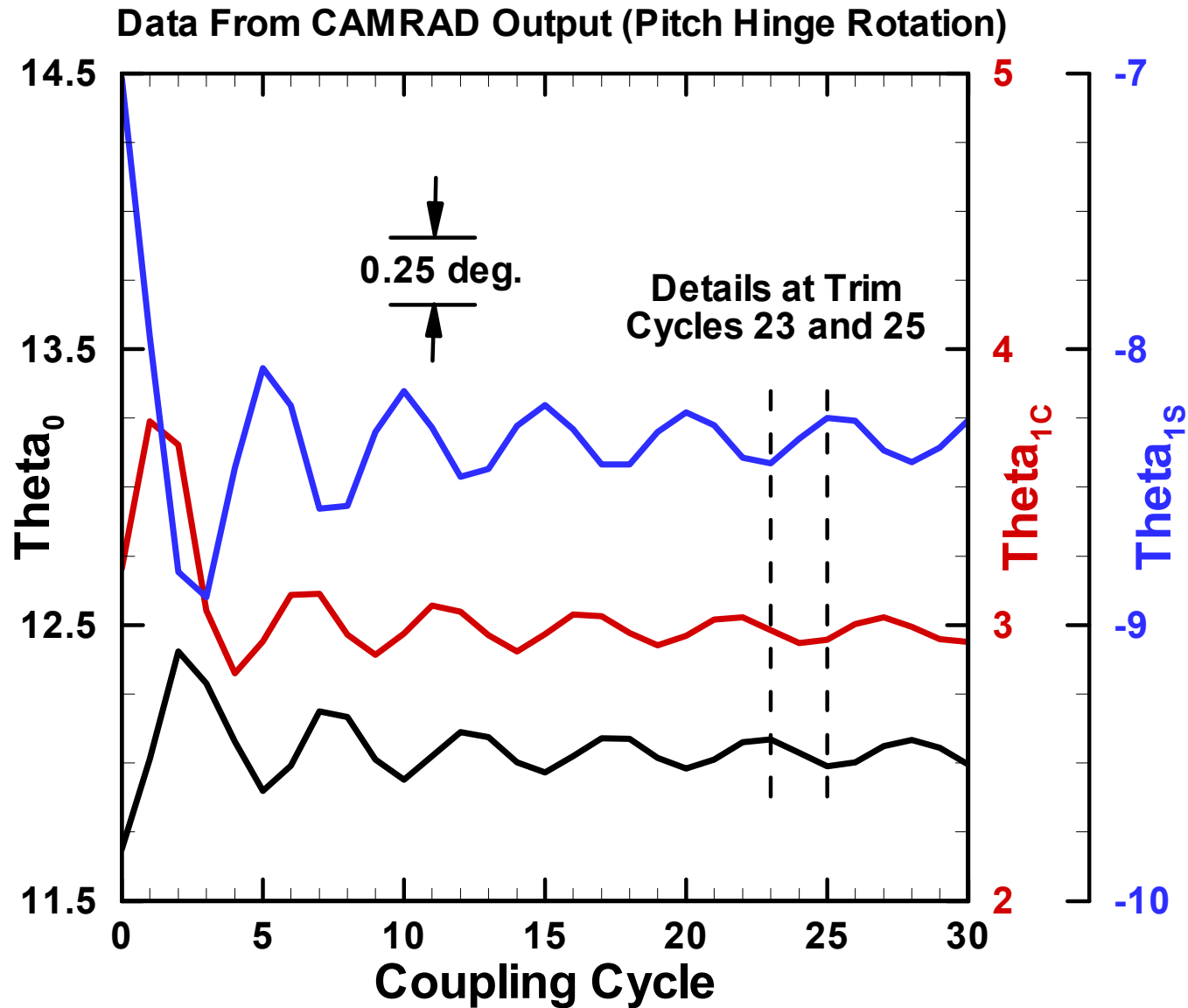
C9017

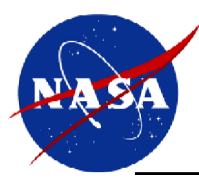
$C_T/\sigma = 0.129$ $\mu = 0.24$

**Rotor Only, “Baseline” Mixed-Element Mesh
(15M Nodes)**



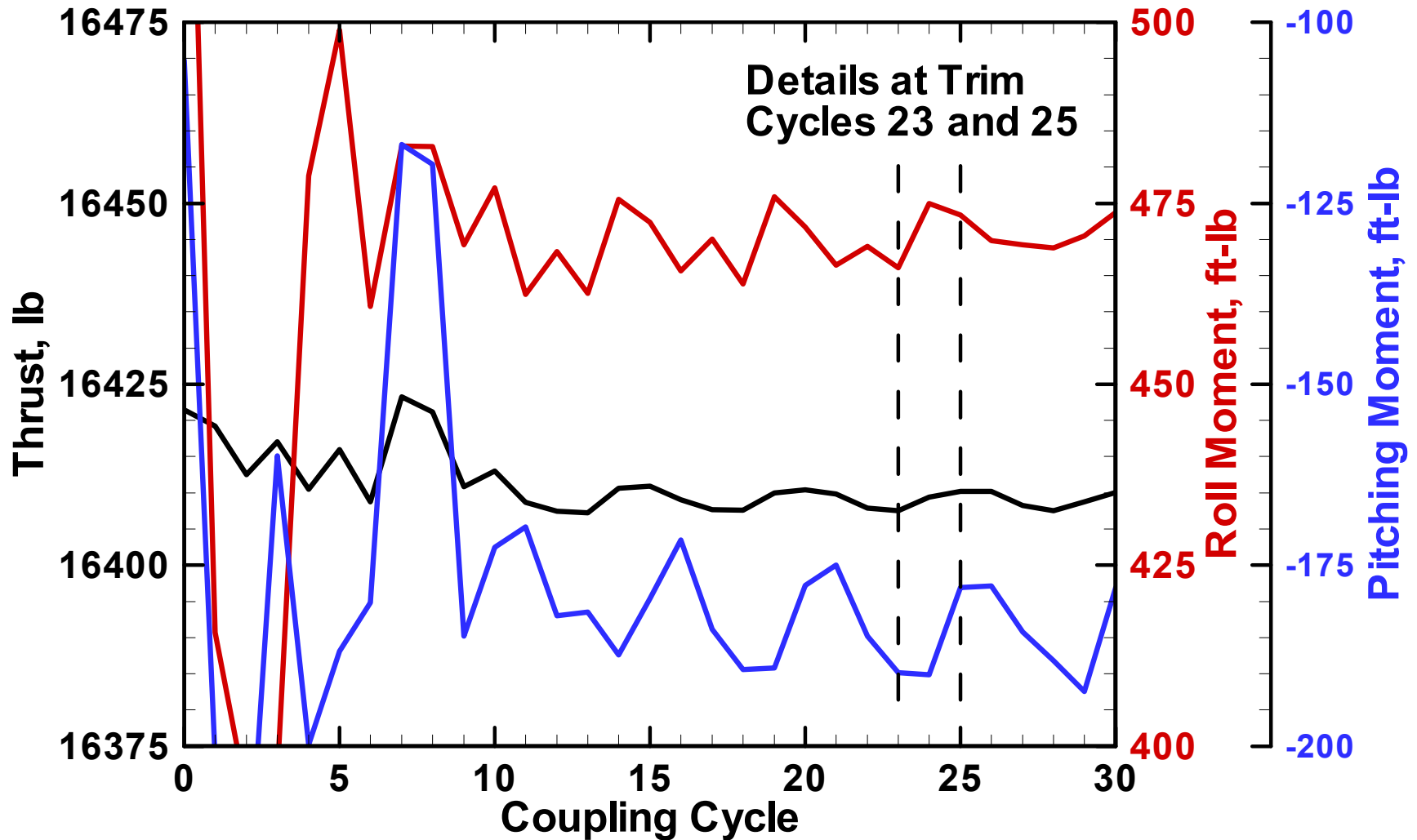
Control Angle Convergence





Trim Force / Moment Convergence

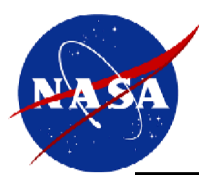
Data From CAMRAD Output



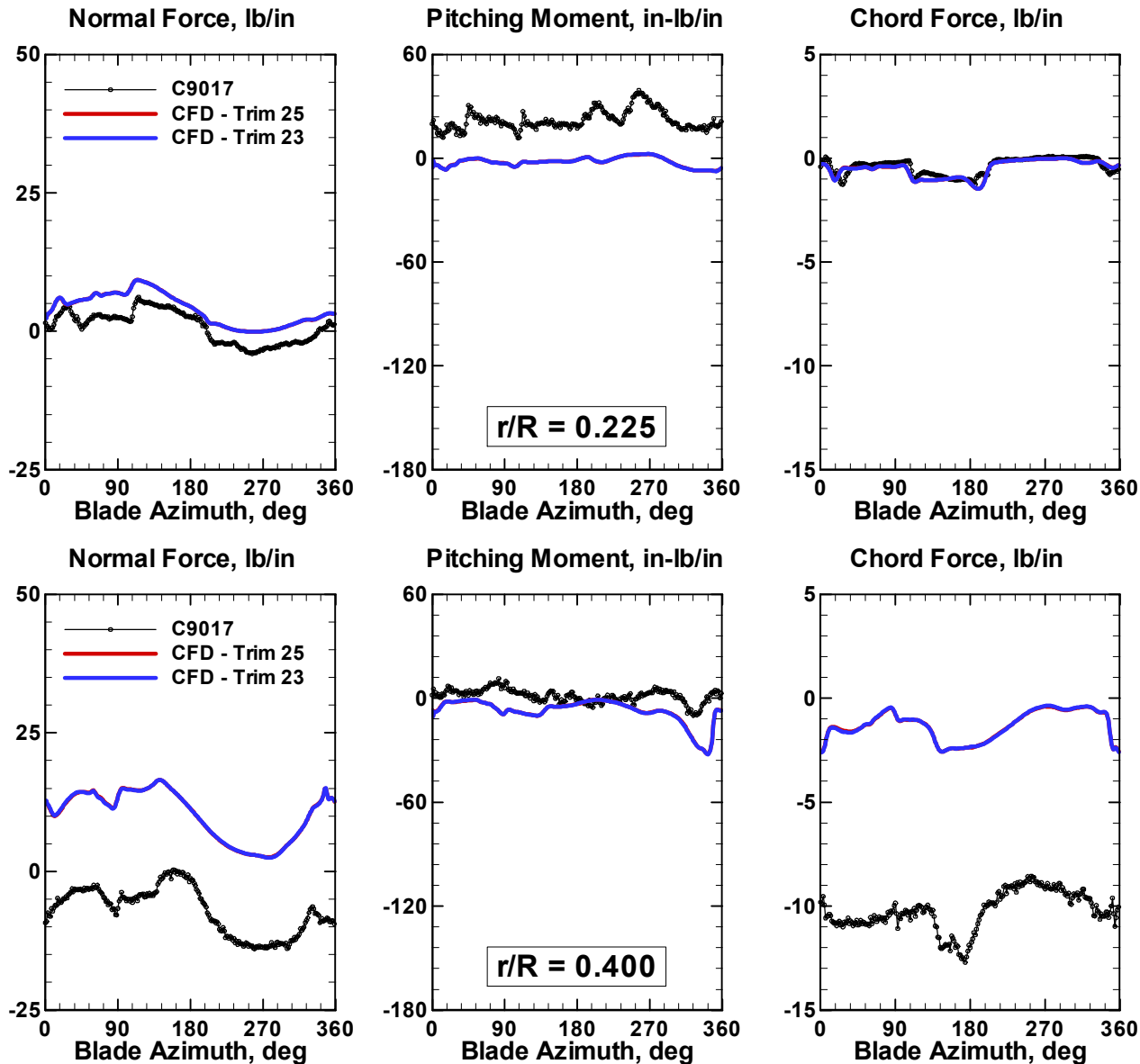


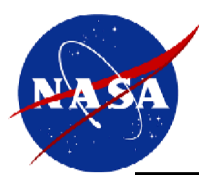
“Converged” vs. Target Values

Quantity	Target	FUN3D/CAMRAD (from CAMRAD)
Thrust (lb)	16452	16409 +/- ~2
Roll Moment (ft-lb)	-379	-471 +/- ~5
Pitch Moment (ft-lb)	-138	-183 +/- ~7

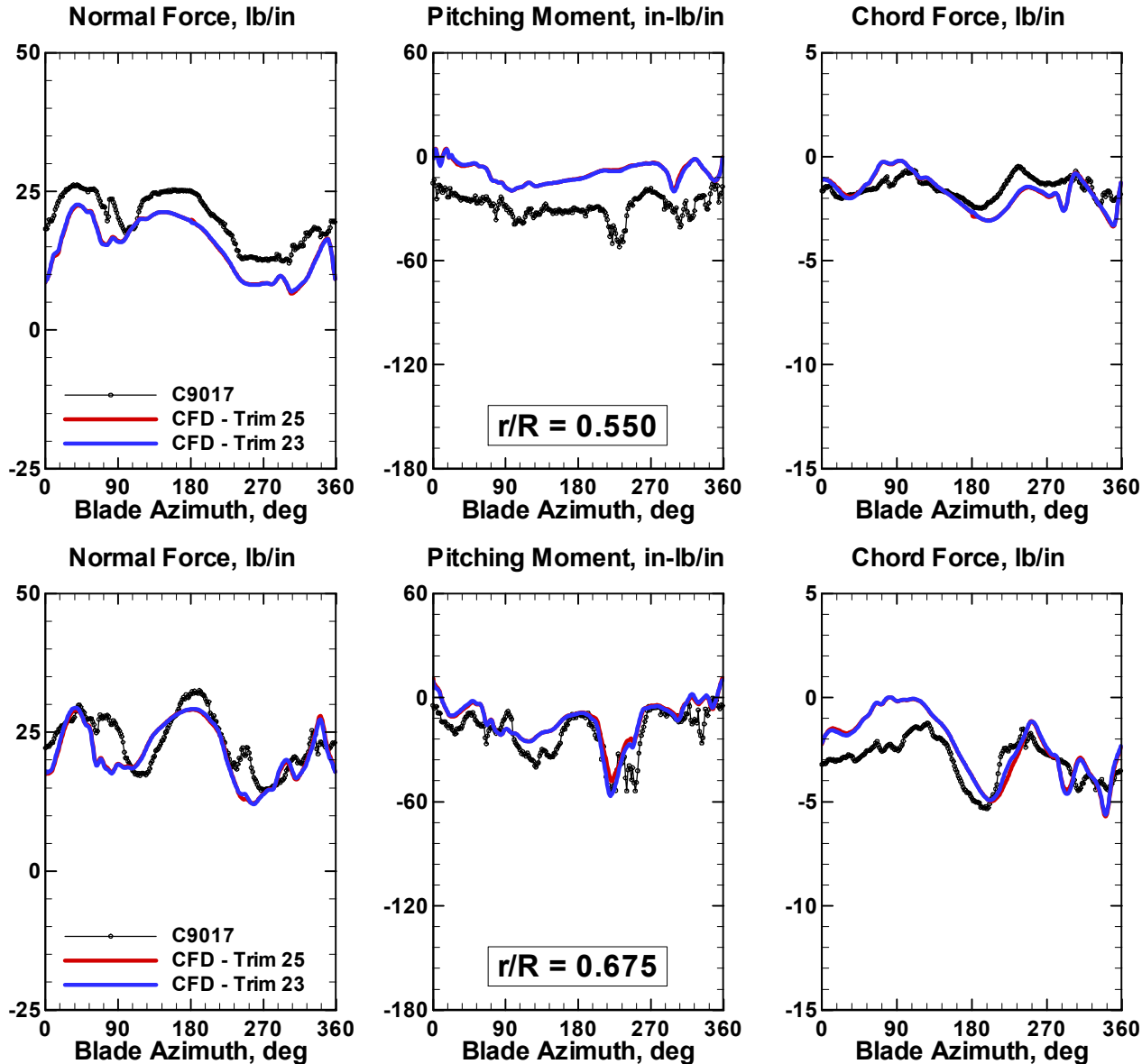


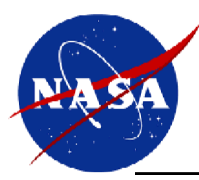
Sectional Airloads (All Harmonics)



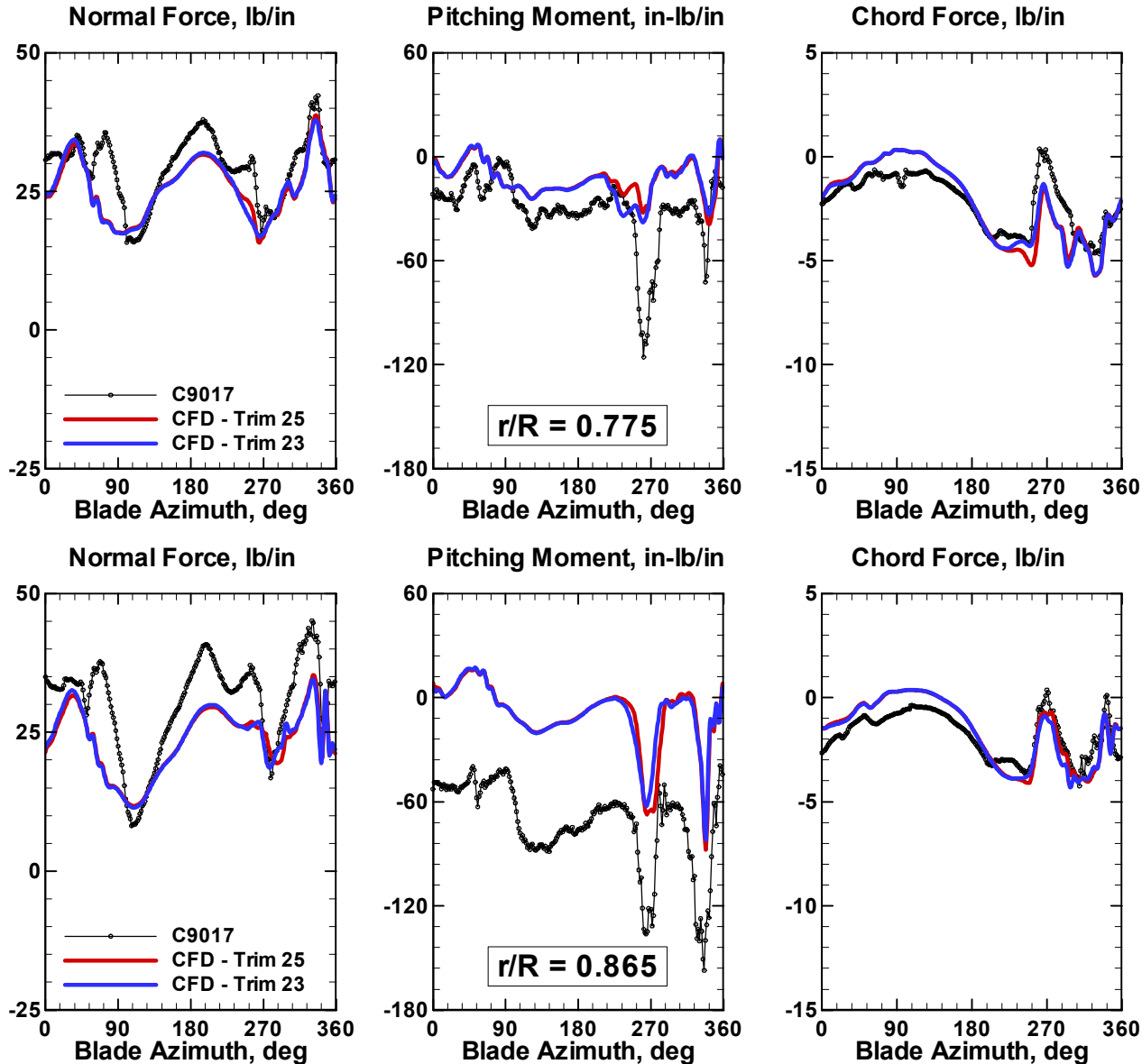


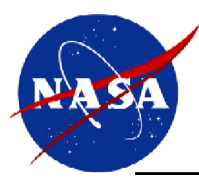
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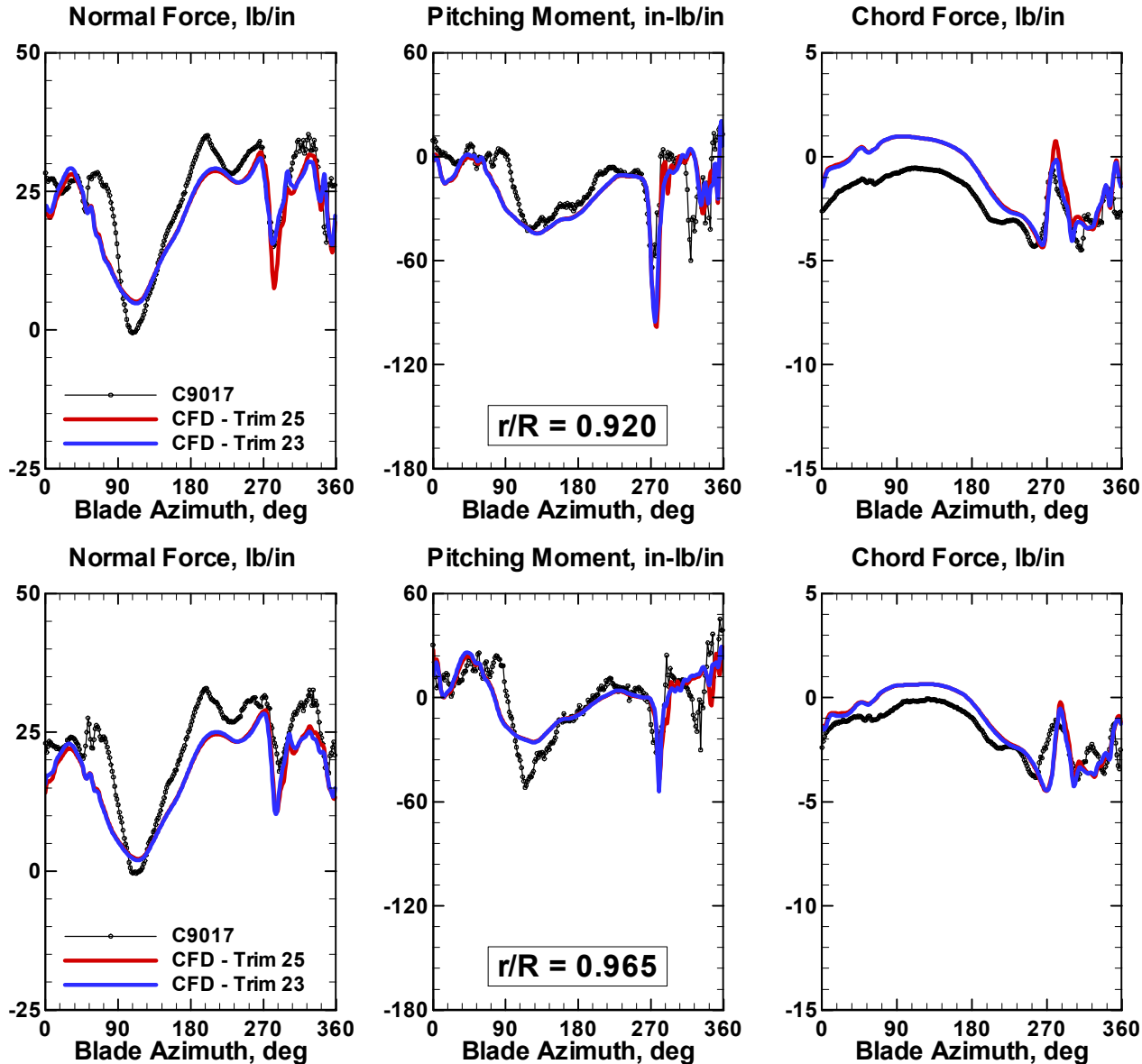


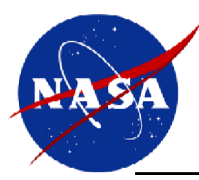
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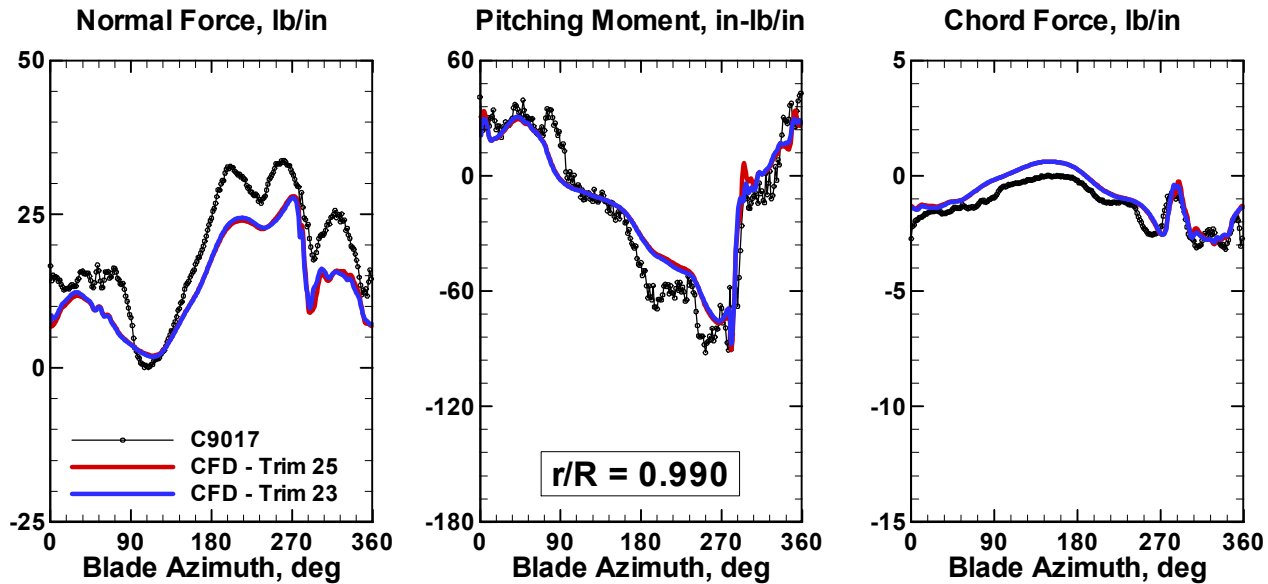


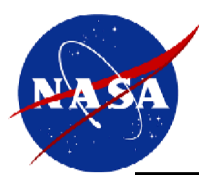
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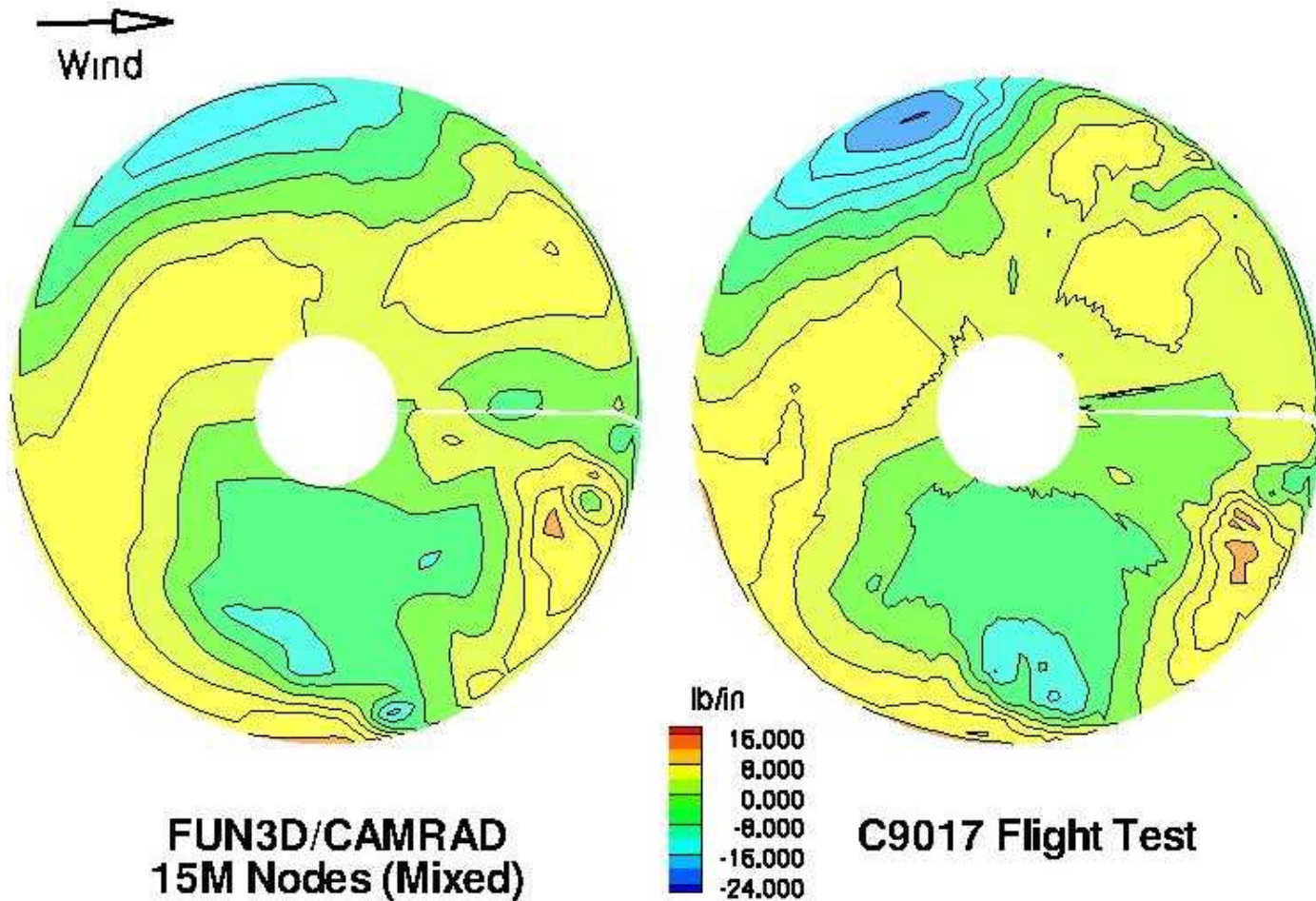


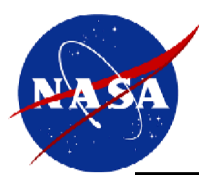
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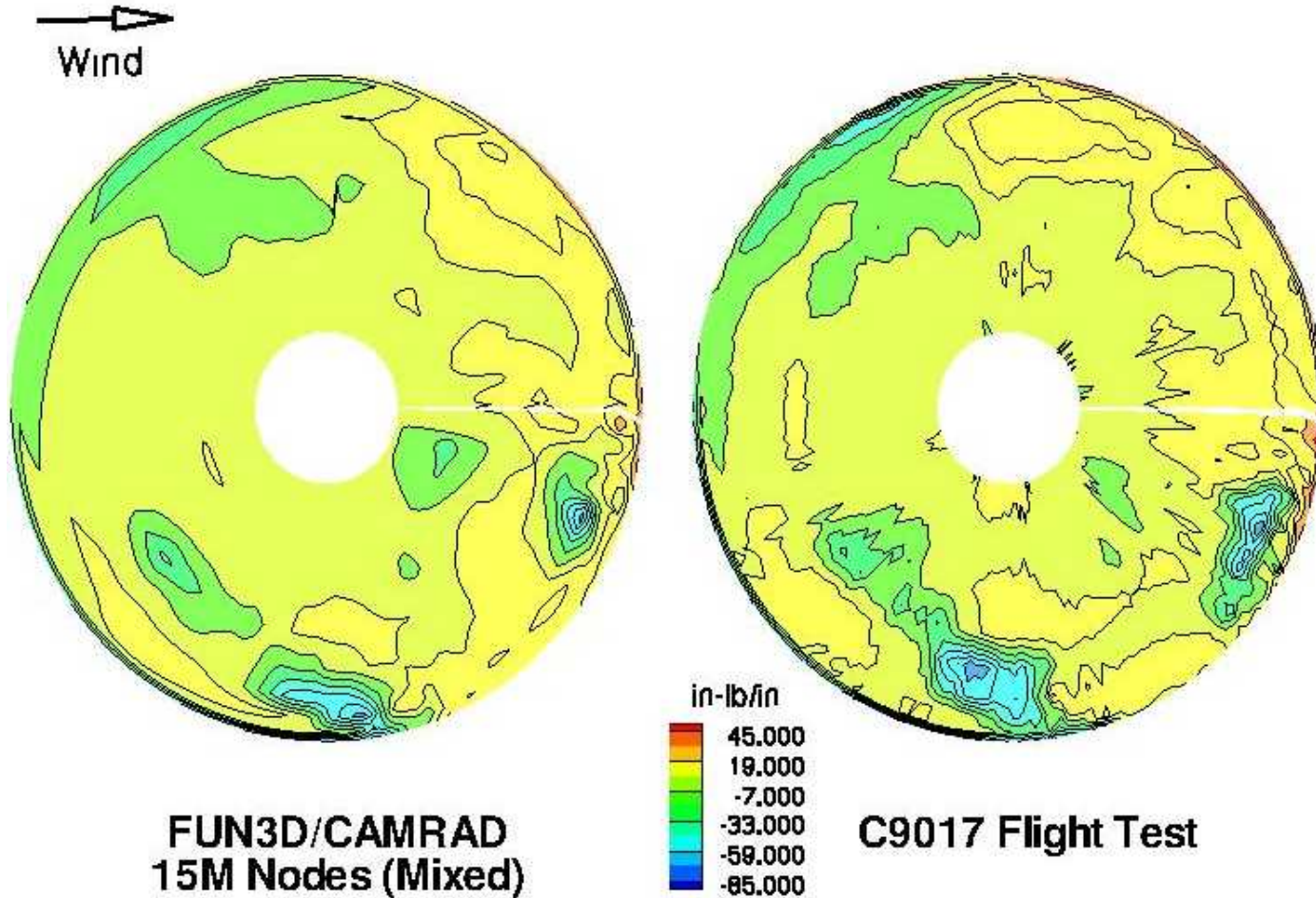


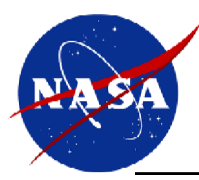
Normal Force Polar Plot (-Mean, Trim 25)



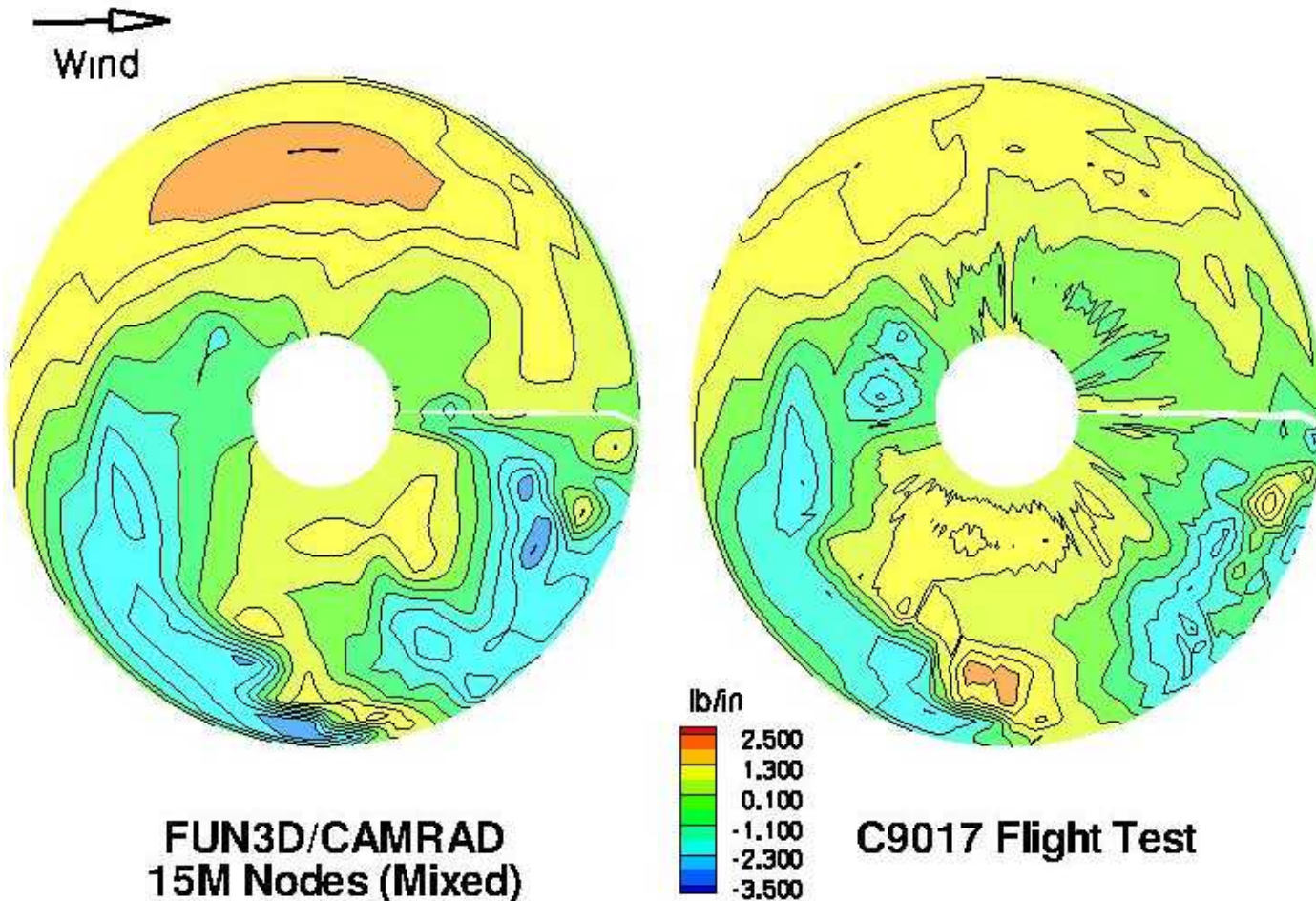


Pitching Moment Polar Plot (-Mean, Trim 25)



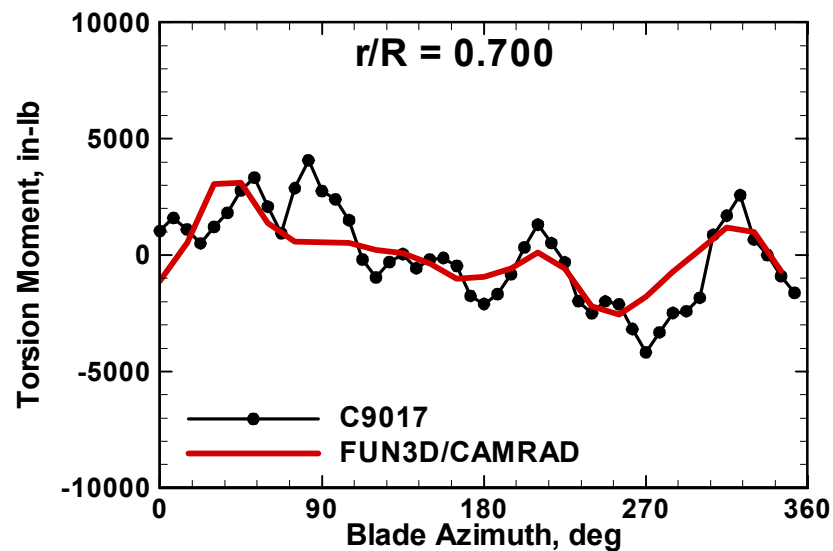
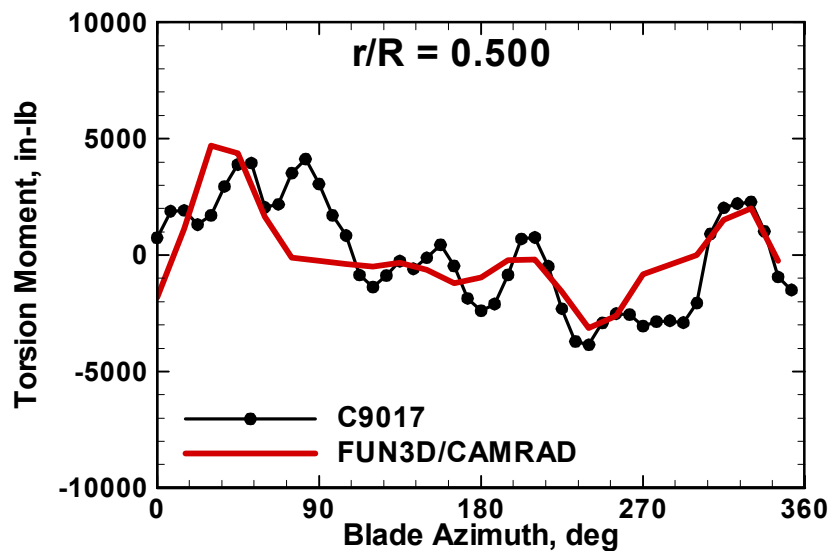
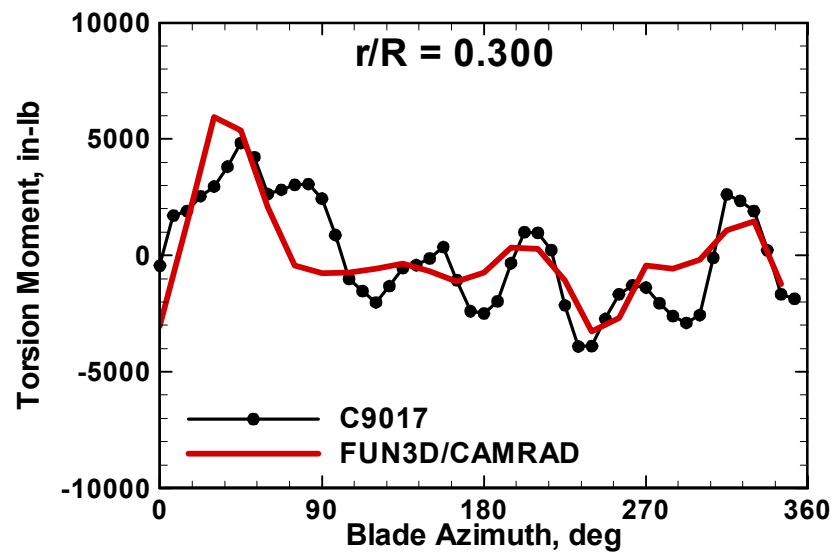
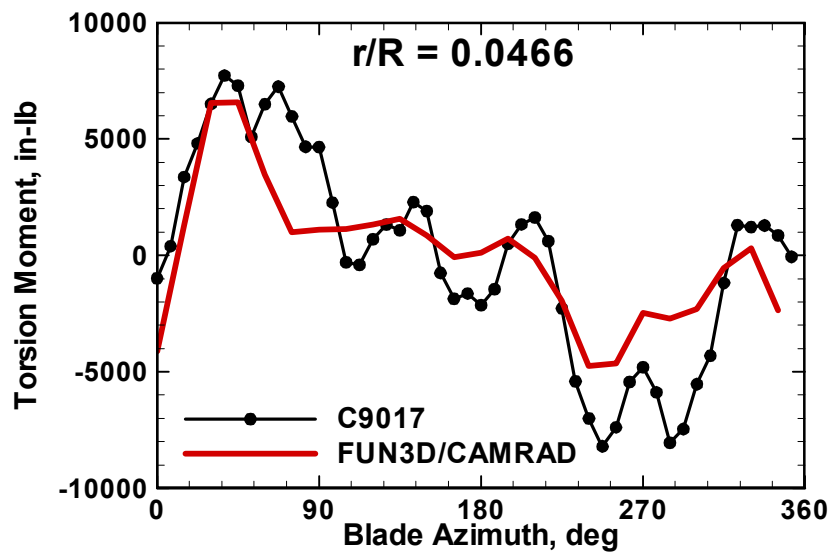


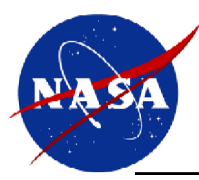
Chord Force Polar Plot (-Mean, Trim 25)



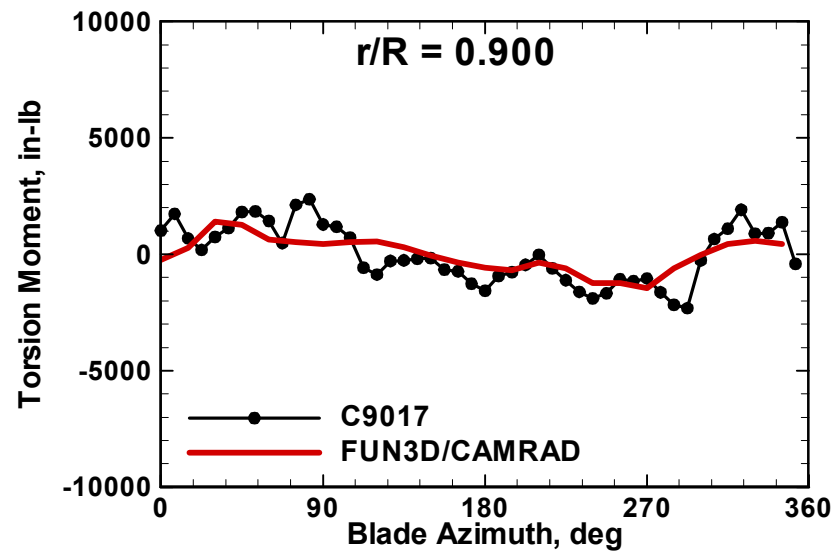


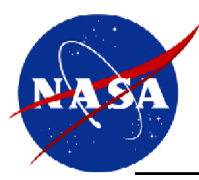
Torsion Moment (-Mean, Trim 25)



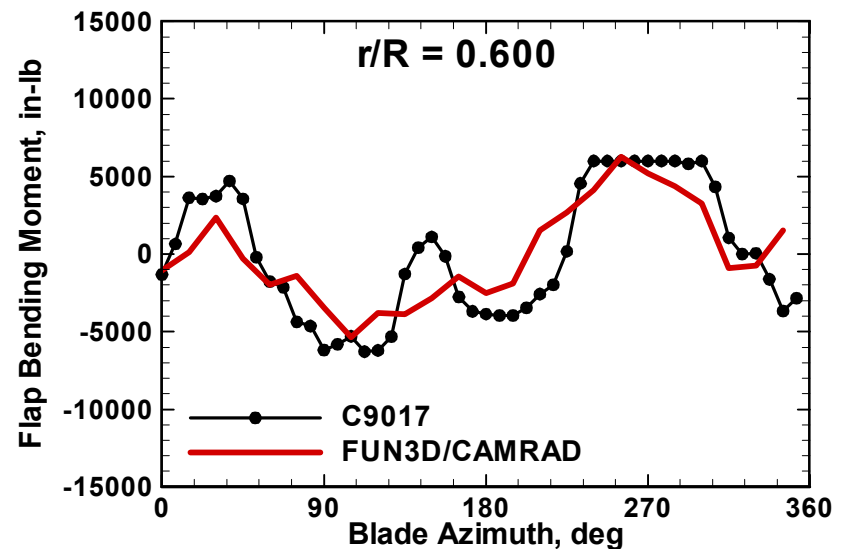
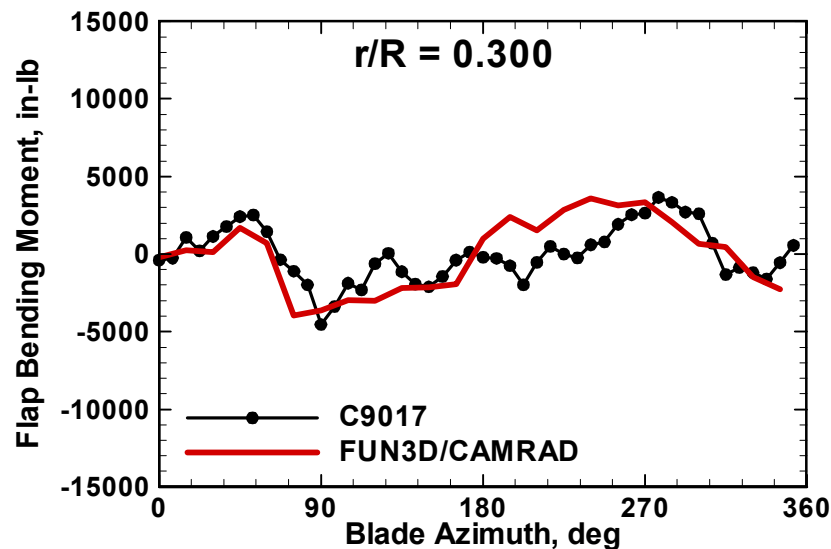
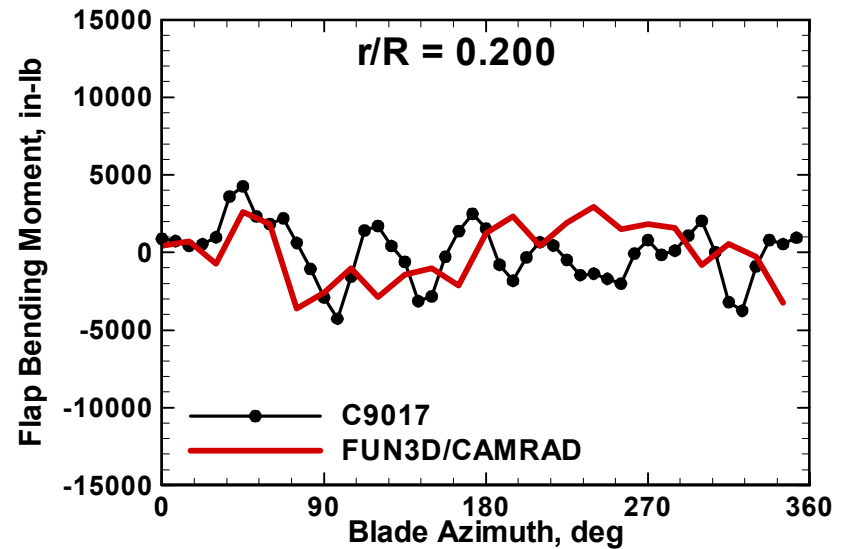
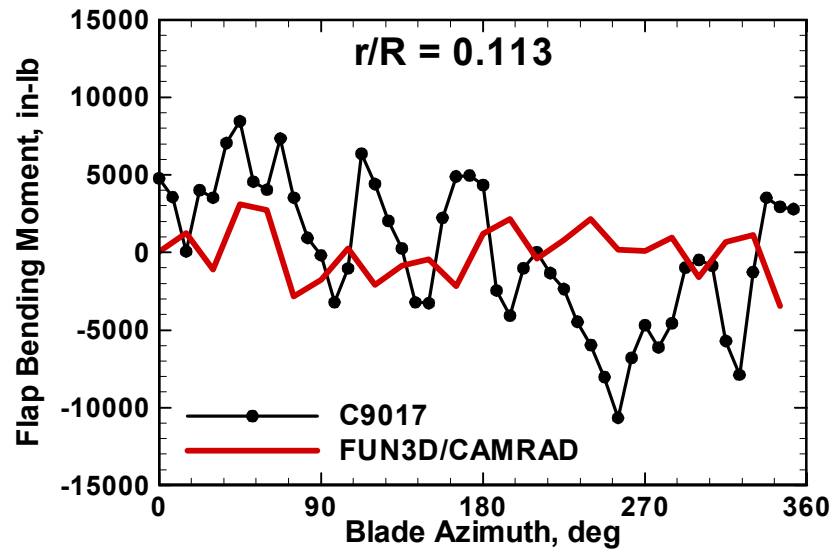


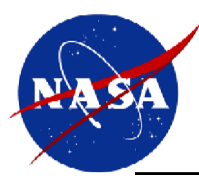
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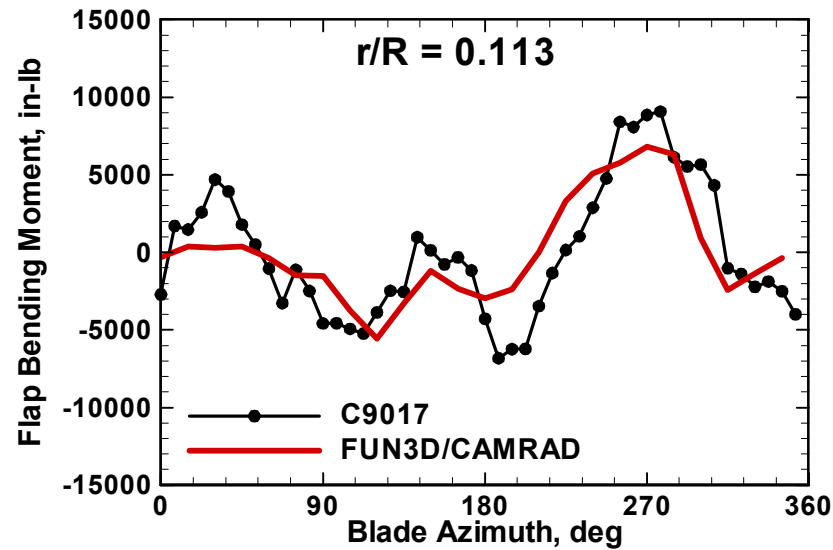


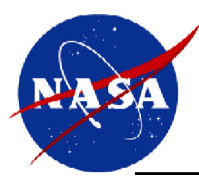
Flap Bending Moment (-Mean, Trim 25)



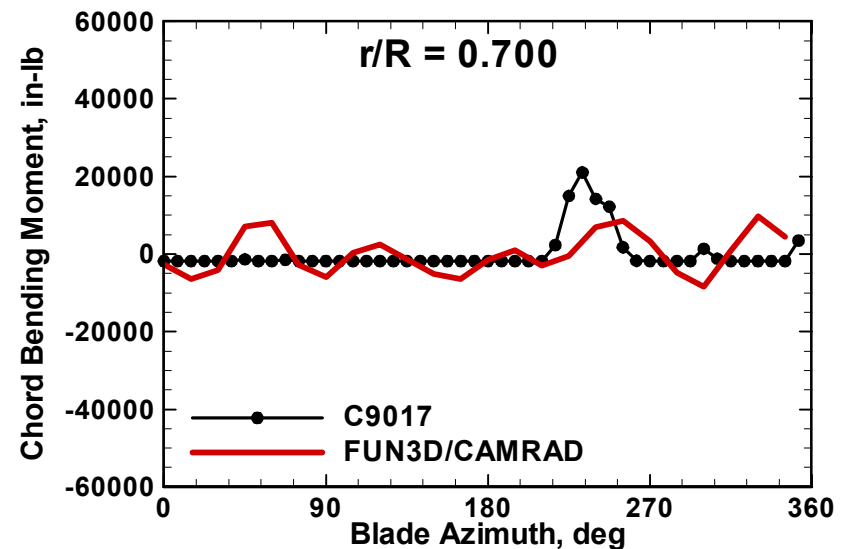
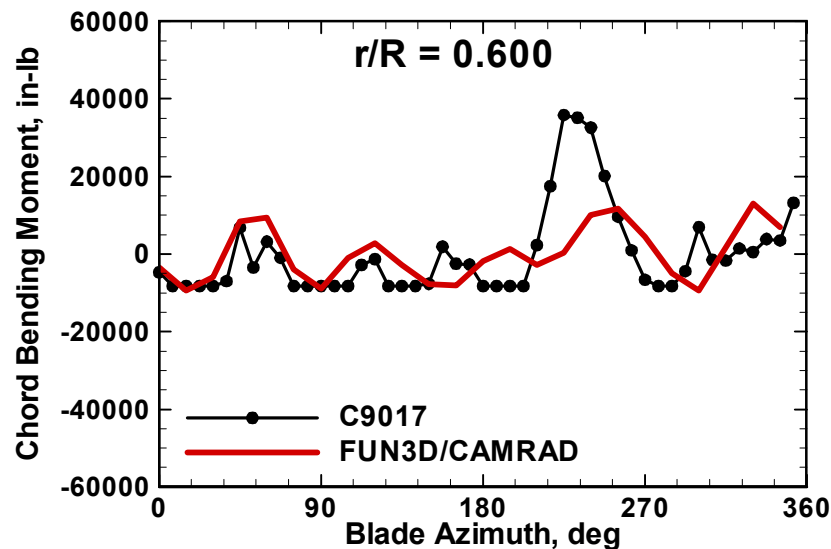
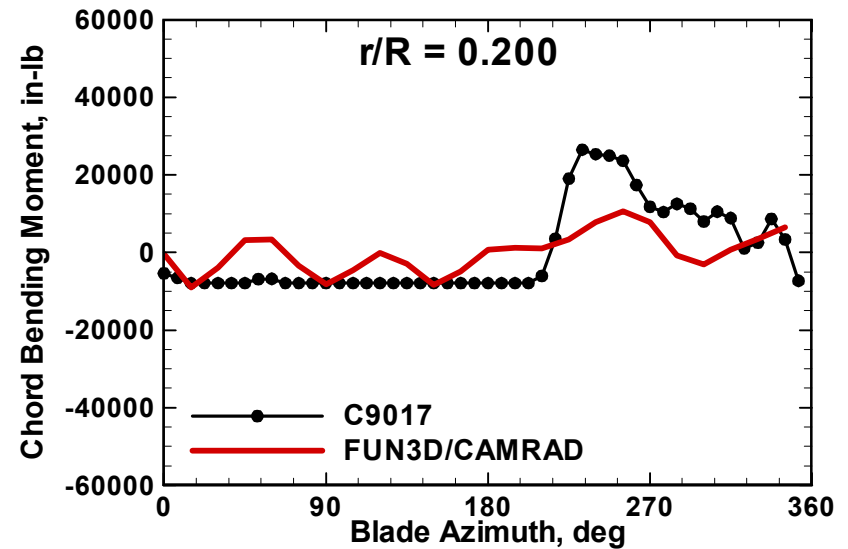
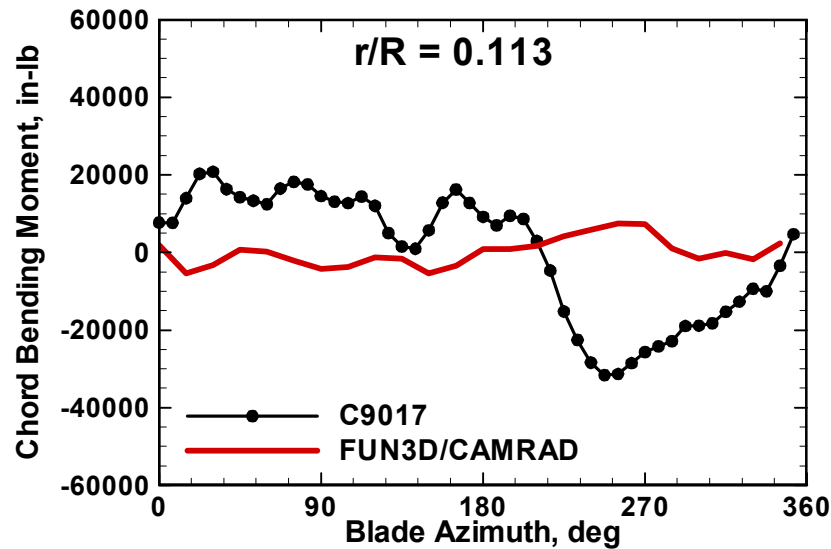


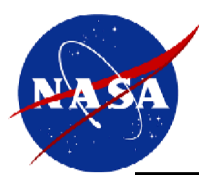
Flap Bending Moment (-Mean, Trim 25)





Chord Bending Moment (-Mean, Trim 25)



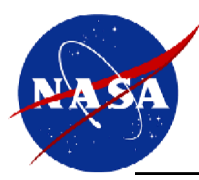


C9017

$$\mathbf{C_T/sigma = 0.129 \quad \mu = 0.24}$$

Rotor Only, “Baseline” Mesh (15M Nodes)

Comparison of Mixed Elements vs. Tetrahedra



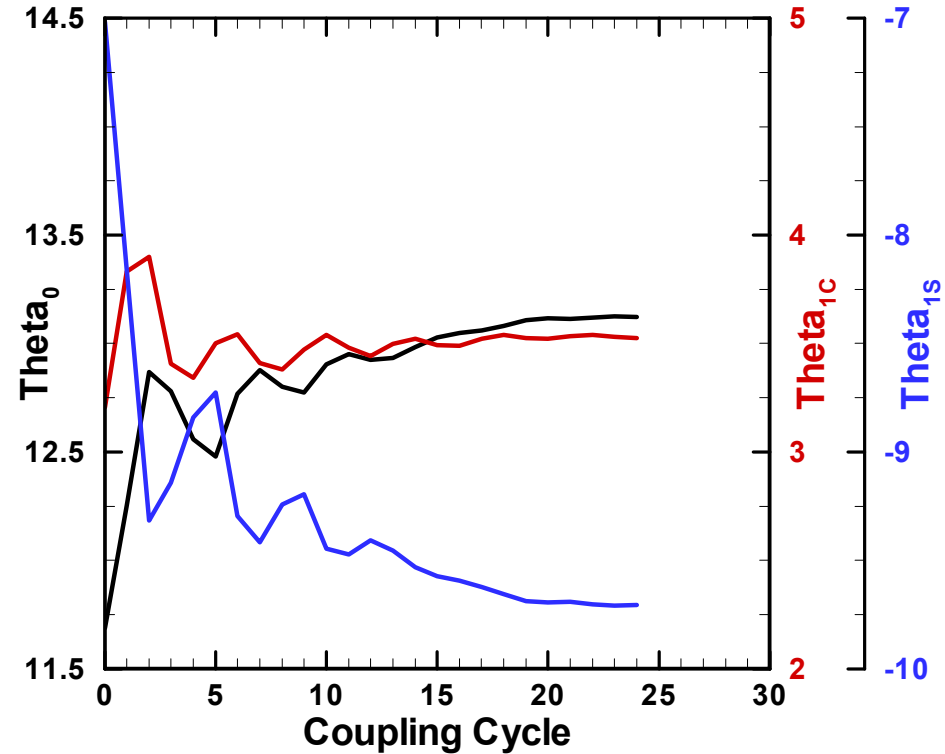
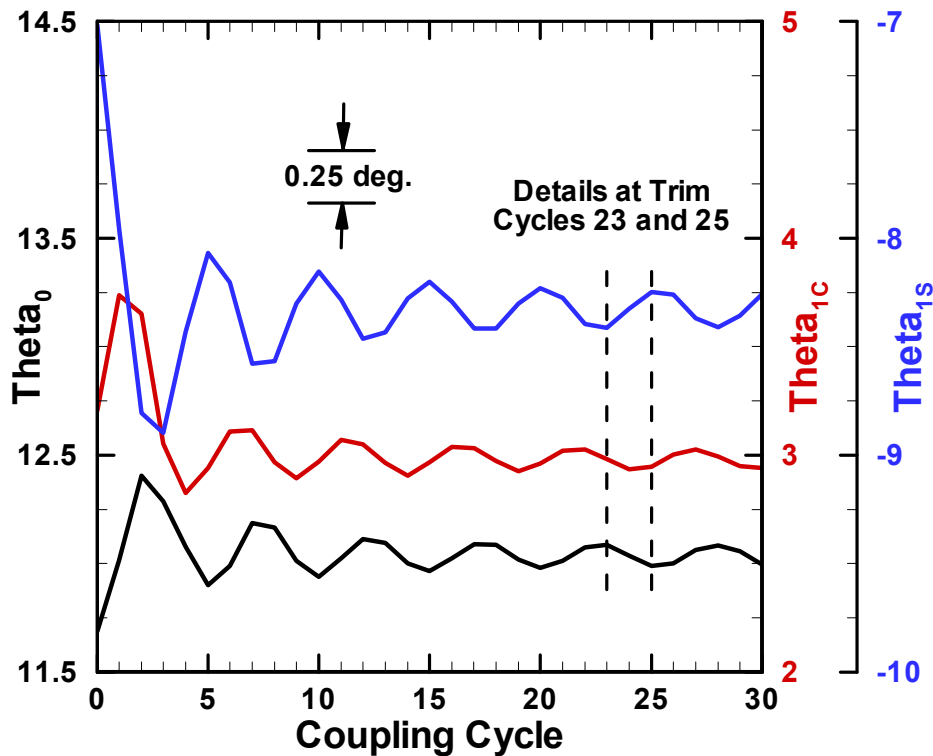
Control Angle Convergence

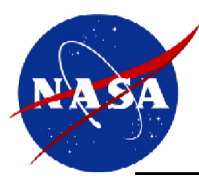
Mixed-Element Mesh (15M)

Tetrahedral Mesh (15M)

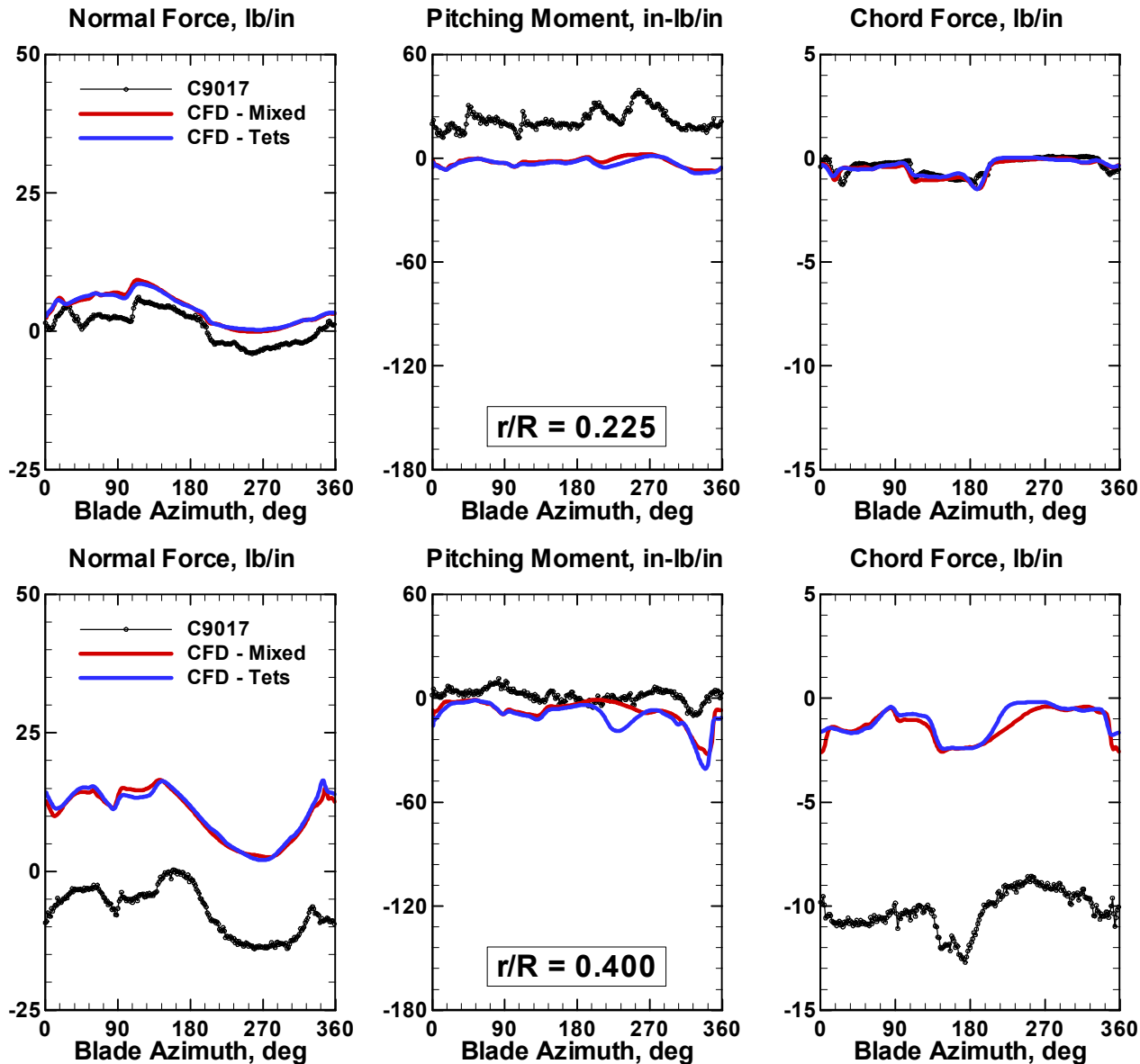
Data From CAMRAD Output (Pitch Hinge Rotation)

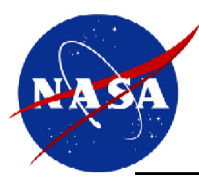
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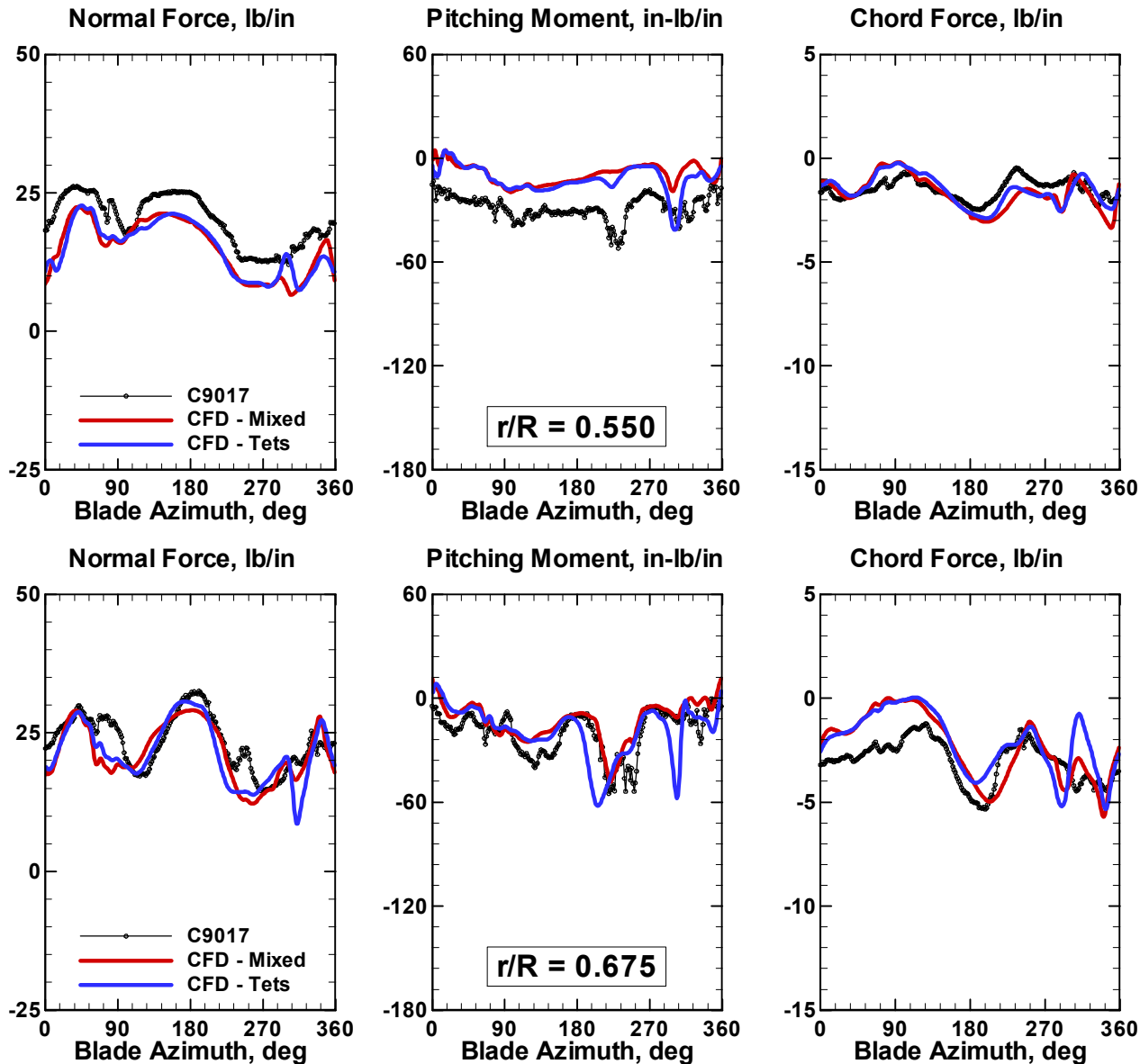


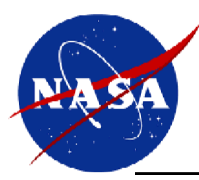
Sectional Airloads (All Harmonics)



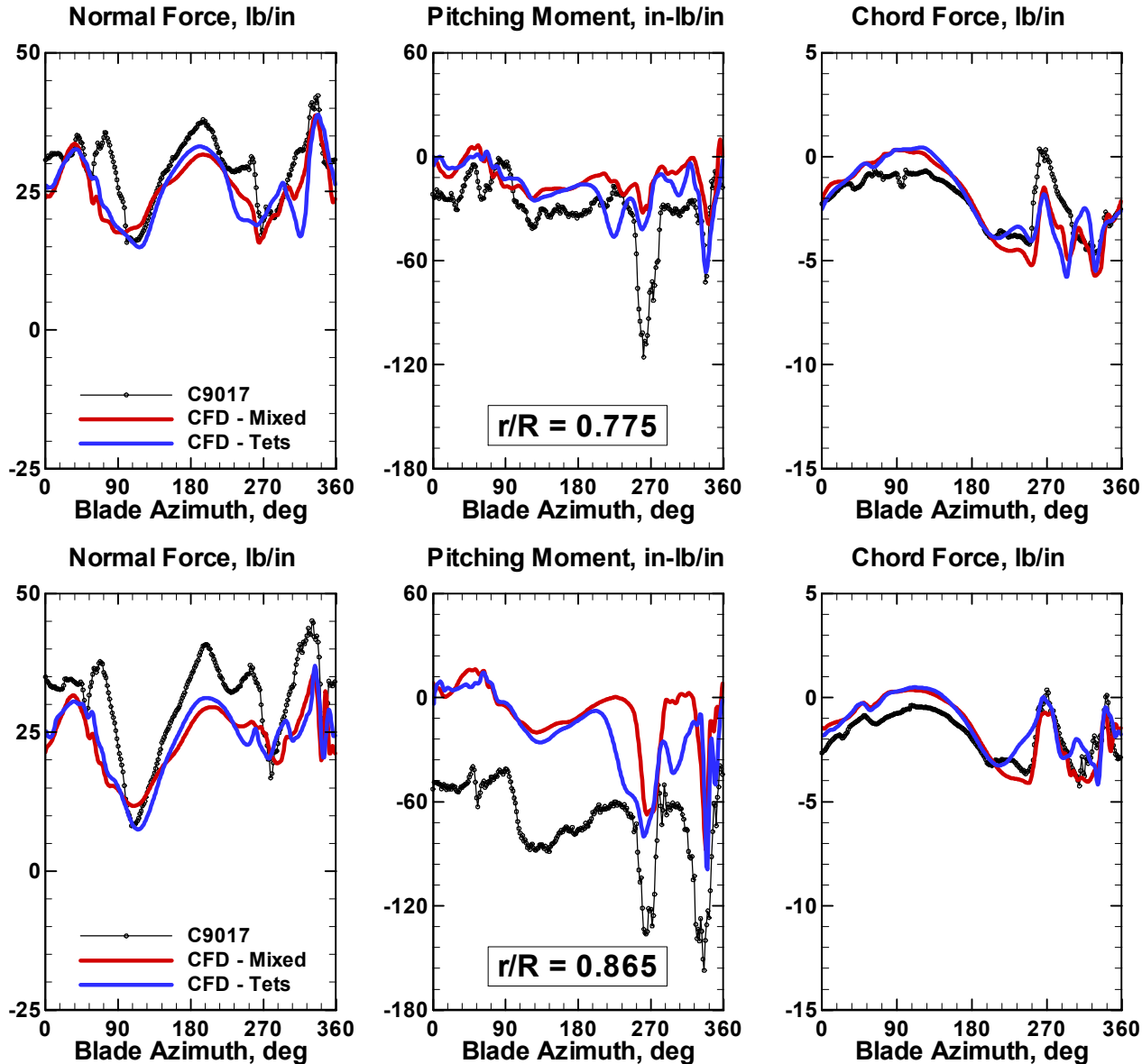


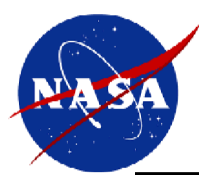
Sectional Airloads



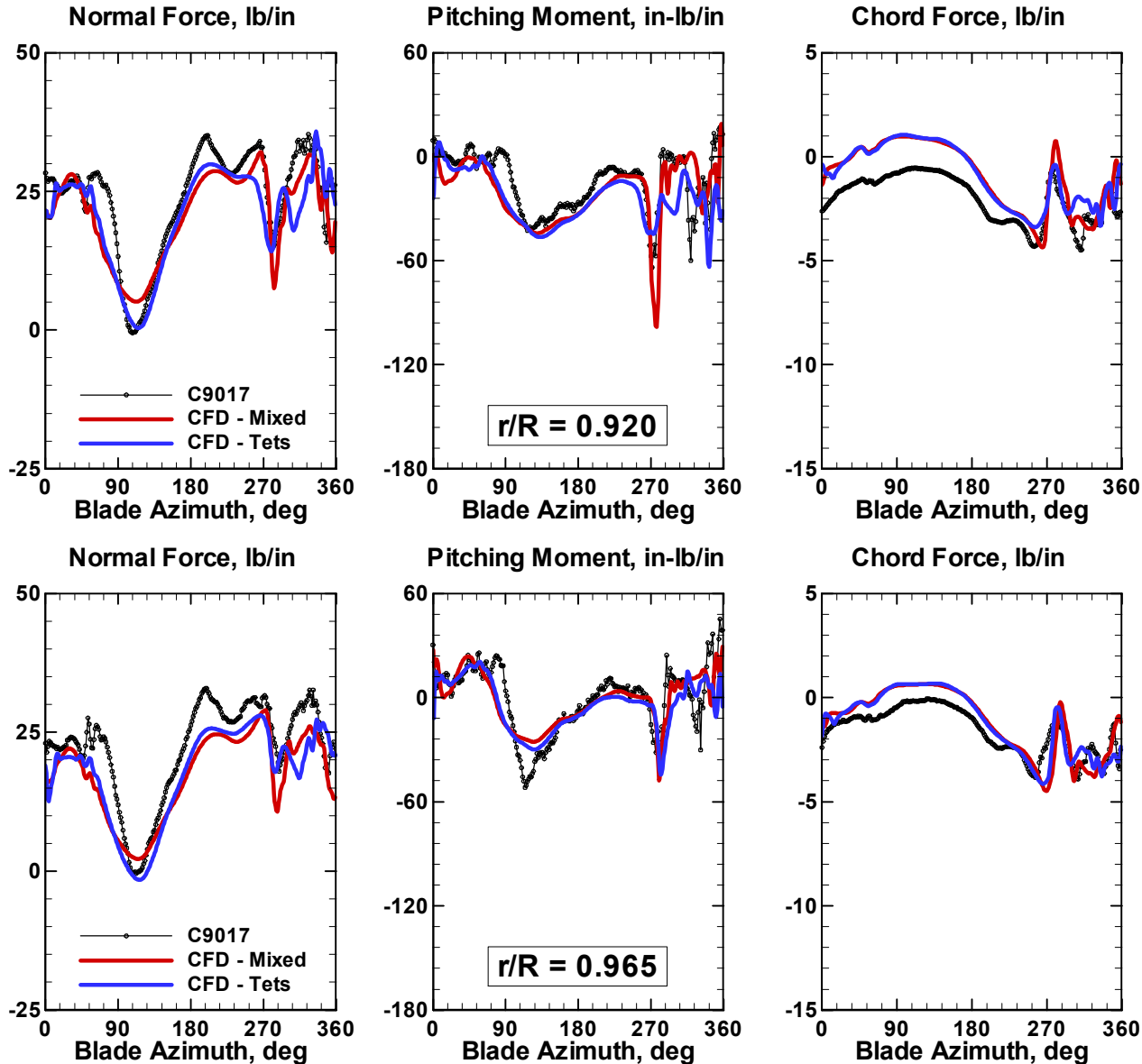


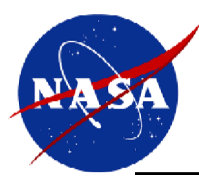
Sectional Airloads



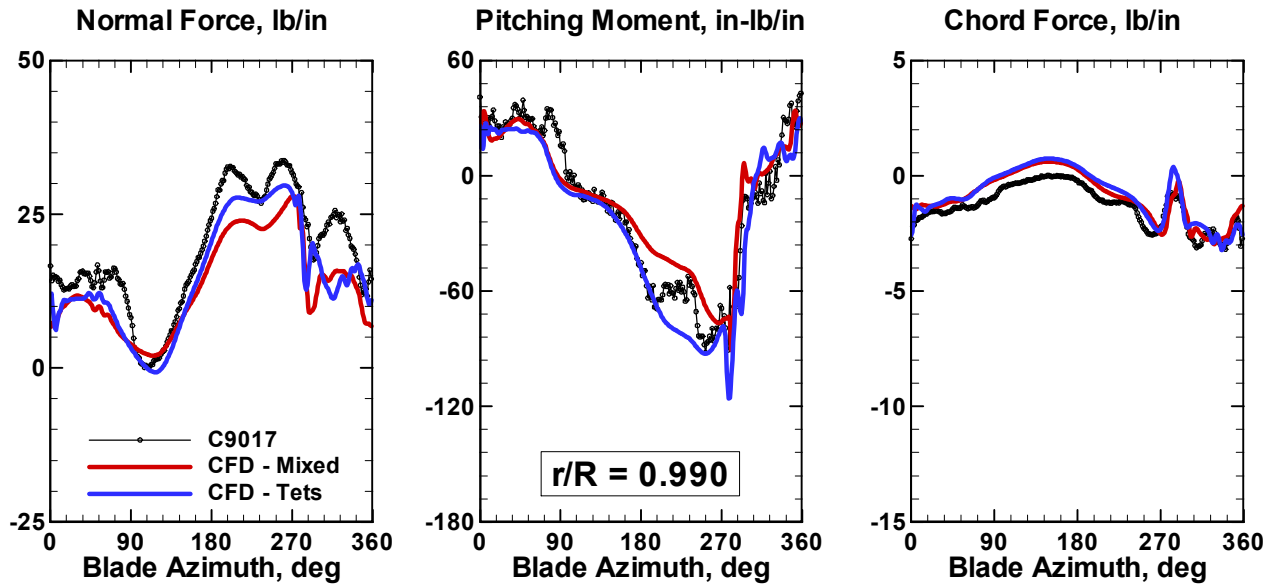


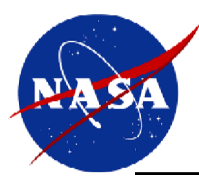
Sectional Airloads





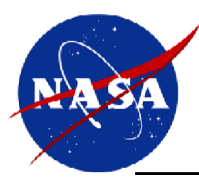
Sectional Airloads





Concluding Remarks

- C9017 is very sensitive to simulation details (as others have observed before)
- Looked at results for two meshes with same grid-point distribution, but different cell topologies in the boundary layer - tetrahedra vs prisms - outside BL, identical tetrahedra
 - Loose coupling with mixed-element mesh reached a limit cycle, with small (< 0.25 deg) control angle changes, and thrust oscillations of ± 2 lb; small oscillation in sectional airloads
 - Loose coupling with tetrahedral mesh rock solid
 - Despite this, detailed sectional loads show improved correlation with flight data for the mixed-element mesh, particularly during dynamic stall events



Extra Material